# DOCUMENT RESUME

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| ED 225 012 | CE 034 965 |
| TITLE | Environmental Support Specialist, Blocks I and II, 17-4. Military Curriculum Materials for Vocational and Technical Education. |
| INSTITUTION | Air Force Training Command, Sheppard AFB, Tex.; Ohio State Univ., Columbus. National Center for Research in Vocational Education. |
| SPONS AGENCY | Office of Education (DHEW), Washington, D.C. |
| PUB DATE | 78 |
| NOTE | 406p.; For related documents see CE 034 966-968. |
| PUB TYPE | Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Guides (For Teachers) (052) |
| EDRS PRICE | MF01/PC17 Plus Postage. |
| DESCRIPTORS | Chemical Analysis; Decimal Fractions; *Environmental Technicians; Fractions; Guidelines; Laboratory Manuals; *Laboratory Procedures; Laboratory Safety; Lesson Plans; Mathematics; Military Personnel; Military Training; Physics; Postsecondary Education; Programed Instruction; Sanitation; *Technical Education; *Waste Disposal; *Waste Water; Water; Water Quality; *Water Treatment; Workbooks |
| IDENTIFIERS | Military Curriculum Project; *Water Analysis |

ABSTRACT

This military-developed text contains the first section of a four-part course to train environmental support specialists. Covered in the individual course blocks are basic mathematics necessary to the study of waste processing and water analysis as well as waste and waste processing and water and water analysis (basic chemistry, air forced water requirements, sources and characteristics of water, laboratory safety, collecting and labeling water and wastewater samples, water analysis, and wastewater analysis). This section contains both teacher and student materials. Printed instructor materials include lesson plans with an outline of teaching steps and a plan of instruction detailing the units of instruction, the duration of the lesson, objectives, and supportive materials needed. Among those student materials provided are two study guides containing objectives, assignments, text readings, and review questions; two workbooks containing exercises and lab work; three programmed texts on fractions, decimals, and physics; and a laboratory manual. (MN)

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ED225012

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# MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

# The National Center Mission Statement

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- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

**FOR FURTHER INFORMATION ABOUT**
**Military Curriculum Materials**
**WRITE OR CALL**

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
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# Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

# Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

**Project Staff:**

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

# What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

# How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

## CURRICULUM COORDINATION CENTERS

**EAST CENTRAL**
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

**MIDWEST**
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

**NORTHEAST**
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225 West State Street
Trenton, NJ 08625
609/292-6562

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Building 17
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Olympia, WA 98504
206/753-0879

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Mississippi State, MS 39762
601/325-2510

**WESTERN**
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1776 University Ave.
Honolulu, HI 96822
808/948-7834

## ENVIRONMENTAL SUPPORT SPECIALIST, BLOCKS I AND II

### Table of Contents

Course Description Page 1

Plan of Instruction Page 3

Block I - Introduction To Water And Waste Processing

Lesson Plans Page 15

Introduction To Water & Waste Processing - Study Guides Page 26

Introduction To Environmental Support - Workbooks Page 36

Block II - Water And Waste Water Analysis

Lesson Plans Page 40

Water and Waste Water Analysis - Study Guides Page 131

Water and Waste Water Analysis - Workbooks Page 182

Laboratory Manual Page 210

Basic Mathematics - Fractions - Programmed Text Page 286

Basic Mathematics - Decimals - Programmed Text Page 324

Basic Physics - Matter - Programmed Text Page 357

# ENVIRONMENTAL SUPPORT SPECIALIST, BLOCKS I AND II

Classroom Course

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**Developed by:**
United States Air Force

**Development and Review Dates:**
September 25, 1975

**D.O.T. No.:**
168.168

**Occupational Area:**
Public Service

**Target Audiences:**
Grades 13-adult

**Print Pages:**
384

**Cost:**

**Availability:**
Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

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| Contents: | Type of Materials: Lesson Plans: | Programmed Text: | Student Workbook: | Handouts: | Text Materials: | Audio-Visuals: | Instructional Design: Performance Objectives: | Tests: | Review Exercises: | Additional Materials Required: | Type of Instruction: Group Instruction: | Individualized: | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. of pages | | | | | | | | | | |
| Block I — *Introduction to Waste and Waste Processing* | | | 4 | | | | | ★ | | | | | |
| Basic Mathematics | ● | ● | | | ● | | ● | | ● | | ● | ● | |
| Block II — *Water and Waste-Water Analysis* | | | 30 | | | | | ★ | | | | | |
| Basic Chemistry | ● | ● | | | ● | ★ | ● | | ● | | ● | | |
| Air Force Water Requirements | ● | | | | ● | | ● | | ● | | ● | | |
| Sources and Characteristics of Water | ● | | | | ● | | ● | | ● | | ● | | |
| Laboratory Safety | ● | | | | ● | ★ | ● | | ● | ★ | ● | | |
| Collecting and Labeling Water and Wastewater Samples | ● | | | | ● | ★ | ● | | ● | ★ | ● | | |
| Water Analysis | ● | | | | ● | ★ | ● | | ● | ★ | ● | | |
| Wastewater Analysis | ● | | | | ● | ★ | ● | | ● | ★ | ● | | |
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★ Materials are recommended but not provided.

THE CENTER FOR VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

Expires July 1, 1978

**Course Description:**

This is the first section of a four-part course to train environmental support specialists. The course includes training in water treatment plants, operating procedures for solid waste disposal, and maintenance of water and waste processing system components. This section gives an introduction to waste and waste processing, and discusses water and water analysis. It consists of two blocks of instruction covering 71 hours.

Block I — *Introduction to Waste and Waste Processing* contains one lesson on basic mathematics covering 10.5 hours of instruction. Five other lessons dealing with the course orientation, career field progression and training, communications security, technical publications, and resources and work force management were deleted.

Block II — *Water and Water Analysis* contains seven lessons covering 60.5 hours of instruction. The lesson topics and respective hours follow:

Basic Chemistry (18 hours)
Air Force Water Requirements (2 hours)
Sources and Characteristics of Water (4 hours)
Laboratory Safety (1 hour)
Collecting and Labeling Water and Wastewater Samples (2 hours)
Water Analysis (18 hours)
Wastewater Analysis (15.5 hours)

This section contains both teacher and student materials. Printed instructor materials include lesson plans with an outline of teaching steps and a plan of instruction detailing the units of instruction, the duration of the lesson, objectives, and support materials needed. Student materials include two study guides containing objectives, assignments, text readings, and review questions; two workbooks containing exercises and lab work; three programmed texts on fractions, decimals, and physics; and a laboratory manual.

Several military technical manuals and commercially produced texts were also referenced but are not provided. Audiovisuals recommended for the entire four sections but not provided are: 20 films, 3 slide sets, and one schematic diagram. This section should be followed by **Environmental Support Specialist, Blocks III-VII** (17-5). It can be presented in a large group instructional setting or adapted for individualized study in waste treatment or ecology courses.

3

CHANGE NOTICE

POI 3ABR56631
(PDS Code AWT)

# PLAN OF INSTRUCTION
## (Technical Training)

17-4

## ENVIRONMENTAL SUPPORT SPECIALIST

AIR TRAINING COMMAND

SHEPPARD TECHNICAL TRAINING CENTER

6 June 1975 - Effective 20 June 1975 with Class 750620
Changed 25 September 1975 - Effective with Class 750818

# MODIFICATIONS

Pages 1-4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

## PLAN OF INSTRUCTION (Continued)

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES | DURATION (HOURS) 2 | SUPPORT MATERIALS AND GUIDANCE 3 |
|---|---|---|
| b. Given several incomplete statements concerning man-hour accounting and work request initiation and processing, select from a list of words or phrases the correct response to complete the statement. | (1.5/0) | Instructional Materials<br>SG 3ABR56330-I-5, Resources and Work Force Management<br>WB 3ABR56330-I-5-P1, Civil Engineer Work Force Management<br>AF Form 332 - Work Request<br>AF Form 1734 - BCE Daily Work Schedule<br>AF Form 1297 - Temporary Issue Receipt |
| c. Using AF supply manuals and catalogs, locate stock numbers and standard nomenclature of desired equipment. | (2/0) | Equipment Condition Tags<br>GSA Catalogs |
| d. Given the condition of equipment, determine the color of tag used to indicate its condition. | (0.3/0) | Training Methods<br>Discussion (4 hrs)<br>Performance (2 hrs) |
| e. Given specific information, issue an item of equipment using AF Form 1297, Temporary Issue Receipt. | (1/0) | Instructional Environment/Design<br>Classroom (4 hrs)<br>Laboratory (2 hrs)<br>Group/Lockstep |
| f. Given related information, identify the individual directly and indirectly responsible for AF property. | (0.7/0) | Instructional Guidance<br>Issue a GSA catalog to each student to complete workbook project. Make sure that each student identifies at least one tagged piece of equipment. |
| 6. Basic Mathematics | 10.5<br>(10.5/0)<br>Days 4 and 5 | Column 1 Reference<br>6a, 6b, 6c<br>STS Reference<br>7d(1), 7d(2), 7d(3), 7d(4), 7d(5), 7d(6), 7d(7), 7d(8), 7d(9), 7d(10), 7d(11), 7d(12), 7d(13), 7d(14), 7d(15), 7d(16), 7d(17) |
| a. Solve problems consisting of whole numbers by using addition, subtraction, multiplication, and division. | (2/0) | 6d, 6e<br>11i |
| b. Solve problems consisting of fractions by using addition, subtraction, multiplication, and division. | (2/0) | Instructional Materials<br>SG 3ABR56330-I-6, Basic Mathematics of Water and Waste Processing<br>WB 3ABR56330-I-6-P1, Basic Mathematics of Water and Waste Processing |

## PLAN OF INSTRUCTION (Continued)

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1 | DURATION (HOURS) 2 | SUPPORT MATERIALS AND GUIDANCE 3 |
|---|---|---|
| c. Solve problems consisting of decimals by using addition, subtraction, multiplication, and division. | (2/0) | 2TPT-5111-01, Basic Mathematics - Fractions<br>2TPT-5111-02, Basic Mathematics - Decimals |
| d. Solve problems for area, consisting of squares, rectangles, and circles. | (2/0) | **Training Methods**<br>Discussion (1 hr)<br>Performance (9.5 hrs) |
| e. Solve problems in volume, ratio, and proportion, and use math formulas. | (2.5/0) | **Instructional Environment/Design**<br>Classroom (1 hr)<br>Laboratory (9.5 hrs)<br>Group/Lockstep<br>**Instructional Guidance**<br>Discuss the need for basic mathematics and show typical problems used in water and waste processing. Issue scratch paper to each student. Each student will do his own work. Solve as many problems as time will permit.<br>Self-study packages 2TPT-5111-01, Basic Mathematics - Fractions, and 2TPT-5111-02, Basic Mathematics - Decimals, will be accomplished in the classroom. |
| 7. Related Training (identified in the course chart) | 10 | |
| 8. Measurement Test and Test Critique | (1.5/0)<br>Day 5 | |

| PLAN OF INSTRUCTION | COURSE TITLE<br>Environmental Support Specialist |
|---|---|

BLOCK TITLE

Water and Wastewater Analysis

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1 | DURATION (HOURS) 2 |
|---|---|
| 1. Basic Chemistry | 18<br>(18/0)<br>Days 6, 7, and 8 |
| a. Provided definitions of chemical terms and a list of elements, radicals, and formulas, identify each with its proper term, symbol, formula, or radical. | (10/0) |
| b. Given a list of acids, bases, and salts, identify each by writing its proper formula and from given formulas, determine which ones are acids, bases, and salts. | (2/0) |
| c. Provided with a list of symbols and radicals, write formulas for the resulting compounds. | (2/0) |
| d. Given incomplete chemical equations, write a balanced equation for each reaction. | (4/0) |

SUPPORT MATERIALS AND GUIDANCE 3

| Column 1 Reference | STS Reference |
|---|---|
| 1a, 1b, 1c, 1d | 7d(1), 7d(2), 7d(3), 7d(4), 7d(5), 7d(6), 7d(7), 7d(8), 7d(9), 7d(10), 7d(11), 7d(12), 7d(13), 7d(14), 7d(15), 7d(16), 7d(17) |

Instructional Materials
SG 3ABR56330-II-1, Basic Chemistry
WB 3ABR56330-II-1-P1, Introduction to Basic Chemistry
WB 3ABR56330-II-1-P2, Testing Acids, Bases, and Salts
2TPT-5120-03, Basic Physics, Matter

Audio Visual Aids
Periodic Chart

Training Methods
Discussion (8 hrs)
Performance (10 hrs)

Instructional Environment/Design
Classroom (8 hrs)
Laboratory (10 hrs)
Group/Lockstep

Instructional Guidance
Use 2TPT-5120-03 in Day 6, WB 3ABR56330-II-1-P1 in Day 7, and WB 3ABR56330-II-1-P2 in Day 8. Emphasize safety in Day 8 when handling acids and bases. Demonstrate the ionization of solutions.

PLAN OF INSTRUCTION (Continued)

| 1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES | 2 DURATION (HOURS) | 3 SUPPORT MATERIALS AND GUIDANCE |
|---|---|---|
| 2. Air Force Water Requirements | 2<br>(2/0)<br>Day 9 | Column 1 Reference<br>2a<br>2b<br>STS Reference<br>7g(1), 7j, 7k<br>7l |
| a. Using related information, list the Air Force water requirements for domestic, fire, and industrial water. | (1.5/0) | Instructional Materials<br>SG 3ABR56330-II-2, Air Force Water Requirements<br>WB 3ABR56330-II-2-P1, Air Force Water Requirements |
| b. Given related information, list the conservation measures of water. | (0.5/0) | Training Methods<br>Discussion (1 hr)<br>Performance (1 hr)<br><br>Instructional Environment/Design<br>Classroom (1 hr)<br>Laboratory (1 hr)<br>Group/Lockstep<br><br>Instructional Guidance<br>Explain the difference in domestic and industrial water. Emphasize the need for water conservation. Emphasize conservation methods. |
| 3. Sources and Characteristics of Water | 4<br>(4/0)<br>Day 9 | Column 1 Reference<br>3a, 3b, 3c<br>STS Reference<br>7g(1) |
| a. Given related information, list the common sources of water. | (1/0) | |

| PLAN OF INSTRUCTION NO. 3ABR56330 | DATE 6 June 1975 | BLOCK NO. II | PAGE 8 |
|---|---|---|---|

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1 | DURATION (HOURS) 2 | SUPPORT MATERIALS AND GUIDANCE 3 |
|---|---|---|
| b. Given the types of impurities that may be found in water and the sources of water, identify the impurities that are normally found in high or low amounts in each source by comparison. | (2/0) | Instructional Materials<br>SG 3ABR56330-II-3, Types and Characteristics of Water Sources<br>WB 3ABR56330-II-3-P1, Common Impurities in Water Supplies<br><br>Training Methods<br>Discussion (3.5 hrs) |
| c. Given a list of water characteristics, write the impurities that will cause each characteristic. | (1/0) | Performance (0.5 hr)<br><br>Instructional Environment/Design<br>Classroom (3.5 hrs)<br>Laboratory (0.5 hr)<br>Group/Lockstep<br><br>Instructional Guidance<br>Discuss the major differences in surface and ground water and the impurities normally found in each. Discuss the advantages and disadvantages of each water source. |
| 4. Laboratory Safety | 1<br>(1/0)<br>Day 10 | Column 1 Reference — STS Reference<br>4a — 7a<br>4b — 7b |
| a. Following oral instructions, apply precautions when handling reagents and chemicals. | (0.5/0) | Instructional Materials<br>SG 3ABR56330-II-4, Laboratory Safety<br>WB 3ABR56330-II-4-P1, Laboratory Safety |
| b. Given actual laboratory equipment, determine proper selection, care and use of the equipment during water and wastewater analysis. | (0.5/0) | Audio Visual Aids<br>TVS-2410, Safety in the Chemical Laboratory<br><br>Training Equipment<br>Laboratory Testing Equipment (1)<br>Laboratory Safety Equipment (1) |

PLAN OF INSTRUCTION (Continued)

| 1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES | 2 DURATION (HOURS) | 3 SUPPORT MATERIALS AND GUIDANCE |
|---|---|---|
| | | **Training Methods**<br>**Discussion (0.8 hr)**<br>**Demonstration (0.2 hr)**<br><br>**Instructional Environment/Design**<br>**Classroom (0.8 hr)**<br>**Laboratory (0.2 hr)**<br>**Group/Lockstep**<br><br>**Instructional Guidance**<br>**Discuss proper methods for handling laboratory glassware. Emphasize emergency procedures for removal of chemical spillage. Discuss safety film after showing.** |
| 5. Collecting and Labeling Water and Wastewater Samples | 2<br>(2/0)<br>Day 10 | Column 1 Reference: 5a, 5b<br>STS Reference: 7c, IIj |
| a. Following written instructions, collect and label a water sample for testing. | (1/0) | Instructional Materials<br>SG 3ABR56330-II-5, Collecting Water and Wastewater Samples<br>WB 3ABR56330-II-5-P1, Collecting Water and Wastewater Samples<br>563X0 Career Ladder Laboratory Manual - All Courses |
| b. Following written instructions, collect and label a wastewater sample for testing. | (1/0) | Audio Visual Aids<br>Schematic of Sewage Plant<br><br>Training Equipment<br>Water Sample Bottle (1)<br>Wastewater Sample Bottle (1)<br><br>Training Methods<br>Discussion (1 hr)<br>Performance (1 hr) |

## PLAN OF INSTRUCTION (Continued)

| 1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES | 2 DURATION (HOURS) |
|---|---|
| 6. Water Analysis | 18<br>(18/0)<br>Days 10, 11, 12 and 13 |
| a. Following written instructions, observing safety precautions, working as a team, and using the colorimetric testing method, determine the amount of chlorine, turbidity, color, fluorides, iron, sulfate, and pH in prepared water samples within ± 15 percent of that present. | (6/0) |
| b. Following written instructions, observing safety precautions, working as a team, and using the volumetric testing method, determine the amount of hardness, alkalinity, chlorides, and carbon dioxide in prepared water samples within ± 15 percent of that present. | (6/0) |
| c. Using a laboratory thermometer and following written instructions, measure the temperature of a water sample to ± $1^{o}$. | (1.5/0) |

3 SUPPORT MATERIALS AND GUIDANCE

**Instructional Environment/Design**

Classroom (1 hr)
Laboratory (1 hr)
Group/Lockstep

**Instructional Guidance**

Direct the students to the demineralizer, latrine wash basin, drinking fountain or laboratory water tap to obtain water sample.
Direct the students to the sewage trainer for the wastewater sample.

| Column 1 Reference | STS Reference |
|---|---|
| 6a | 7a, 7b, 7d(1), 7d(2), 7d(5), 7d(7), 7d(9), 7d(11), 7d(16), 111(4), 111(5) |
| 6b | 7a, 7b, 7d(3), 7d(4), 7d(14), 7d(17) |
| 6c | 7d(8), 111(6) |
| 6d | 7a, 7d(1) |
| 6e | 7d(12), 7d(15) |
| 6f | 7a, 7b, 7d(13) |

**Instructional Materials**

SG 3ABR56330-II-6, Water Analysis
WB 3ABR56330-II-6-P1, Determining Types of Hardness
WB 3ABR45330-II-6-P2, Problems on Alkalinity
563X0 Career Ladder Laboratory Manual-All Courses

**Audio Visual Aids**

TF 6197-a, b, and d, Methods of Water Testing

**Training Equipment**

Laboratory Equipment (1)
Direct Reading Colorimeter (2)
Water Analysis Kit (2)
Electric Lab Stirrer (2)

PLAN OF INSTRUCTION (Continued)

| 1 UNITS OF INSTRUCTION AND CRITERION OBJECTIVES | 2 DURATION (HOURS) | 3 SUPPORT MATERIALS AND GUIDANCE |
|---|---|---|
| d. Following written instructions, observing safety precautions, working as a team, and using an electric meter, determine the pH of a water sample to ± 0.5 pH unit. | (1.5/0) | **Training Methods**<br>Discussion (2.5 hrs)<br>Demonstration (2.5 hrs)<br>Performance (13 hrs) |
| e. Given related information, state the method used to perform the phosphate and silica test. | (1.5/0) | **Instructional Environment/Design**<br>Classroom (2.5 hrs)<br>Laboratory (15.5 hrs)<br>Group/Lockstep |
| f. Using test equipment and written instructions, perform the jar test to determine minimum chemical dosage. | (1.5/0) | **Instructional Guidance**<br>Demonstrate the use of laboratory equipment using the four methods of testing. Prepare all water samples for the day's instructions. Demonstrate the test for polyphosphates and silicates. Discuss the method of testing for radioactivity. Show film before performance in laboratory. |
| 7. Wastewater Analysis | 15.5<br>(13.5/2)<br>Days 13, 14 and 15 | **Column 1 Reference** — **STS Reference**<br>7a — 7d(10), 11k, 11l(7)<br>7b — 11k, 11l(1)(c)<br>7c — 11k, 11l(1)(a), 11l(1)(d), 11l(1)(e)<br>7d — 11l(1)(b)<br>7e — 11k, 11l(2), 11l(3) |
| a. Following written instructions, using laboratory equipment, observing safety precautions, and working as a team, perform a dissolved oxygen test on a prepared water sample to ± 2 ppm. | (3/0) | **Instructional Materials**<br>SG 3ABR56330-II-7, Wastewater Analysis<br>WB 3ABR56330-II-7-P1, Operating the Blue M Lab-Heat Muffle Furnace<br>AFM 85-14, Maintenance and Operation of Sewage and Industrial Waste Plants and Systems<br>563X0 Career Ladder Laboratory Manual-All Courses |
| b. Using an Imhoff cone and written instructions, working as a team and observing safety precautions, determine the volume of settleable solids in a wastewater sample to ± 5 ml/l. | (1/0) | |

**PLAN OF INSTRUCTION (Continued)**

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1 | DURATION (HOURS) 2 | SUPPORT MATERIALS AND GUIDANCE 3 |
|---|---|---|
| c. Using the gravimetric method of testing and following written instructions, working as a team and observing safety precautions, determine the amount of suspended solids, total solids, and volatile solids in a prepared wastewater sample within ± 15 percent of that present. | (7.5/2) | Audio Visual Aids<br>TF 6197-c, Methods of Water Testing<br><br>Training Equipment<br>Laboratory Equipment (1)<br>Prepared Wastewater Samples (1)<br>Drying Oven (12)<br>Muffle Furnace (12)<br>Analytical Balance (6)<br>Electric pH Meter (2)<br>Water Analysis Kit (2)<br><br>Training Methods<br>Discussion (1.5 hrs)<br>Demonstration (1 hr)<br>Performance (11 hrs)<br>Outside Assignment (2 hrs)<br><br>Instructional Environment/Design<br>Classroom (1.5 hrs)<br>Laboratory (12 hrs)<br>Study Hall (2 hrs)<br>Group/Lockstep<br><br>Instructional Guidance<br>Demonstrate the use and care of the analytical balance. Observe the students in the use of precision equipment.<br>Demonstrate the use of tongs when handling hot dishes. Emphasize safety in using the drying ovens. |
| d. Using the test results from the total and suspended solids tests, compute the amount of dissolved solids in a wastewater sample. | (0.5/0) | |
| e. Using laboratory equipment and following written instructions, working as a team and observing safety precautions, correctly prepare the samples needed to determine biochemical oxygen demand and relative stability of wastewater. | (1.5/0) | |

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| PLAN OF INSTRUCTION NO. 3ABR56330 | DATE 6 June 1975 | BLOCK NO. II | PAGE NO. 13 |

## PLAN OF INSTRUCTION (Continued)

| UNITS OF INSTRUCTION AND CRITERION OBJECTIVES 1 | DURATION (HOURS) 2 | SUPPORT MATERIALS AND GUIDANCE 3 |
|---|---|---|
| | | Students may perform more than one test at a time. Emphasize safety when handling strong acids.<br>**Outside Assignment:**<br>On day 14, direct the students to review the block study guides and workbooks to prepare for the measurement test. |
| 8. Related Training (as stated in course chart) | 18 | |
| 9. Measurement Test and Test Critique | (1.5/0)<br>Day 15 | |

17-4 18

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>I | BLOCK TITLE<br>Introduction to Water and Waste Processing |

LESSON TITLE
Basic Mathematics (Days 4, 5)

**LESSON DURATION**

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 10.5 Hrs | 0 | 10.5 Hrs |

**POI REFERENCE**

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 5 | 6 June 1975 | 6 |

**STS/CTS REFERENCE**

| NUMBER | DATE |
|---|---|
| STS 563X0 | 28 July 1971 |

**SUPERVISOR APPROVAL**

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**PRECLASS PREPARATION**

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| None | None | None | SG I-6<br>WB I-6-P1<br>2TPT-5111-01<br>2TPT-5111-02 |

**CRITERION OBJECTIVES AND TEACHING STEPS**

6a. Solve problems consisting of whole numbers by using addition, subtraction, multiplication, and division.

(1) Addition - sum
(2) Subtraction - remainder
(3) Multiplication - product
(4) Division - quotient

6b. Solve problems consisting of fractions by using addition, subtraction, multiplication, and division.

(1) Definition of a fraction
(2) Types of fractions
(3) Parts of fractions
(4) Rules for solving problems

ATC FORM AUG 72 770

LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

6c. Solve problems consisting of decimals by using addition, subtraction, multiplication, and division.

(1) Definition of decimals
(2) Reading decimals
(3) Conversion of fractions to decimals
(4) Conversion of decimals to fractions
(5) Rounding off decimals
(6) Rules for solving problems

6d. Solve problems for area, consisting of squares, rectangles, and circles.

(1) Squares
(2) Rectangles
(3) Circles

6e. Solve problems in volume, ratio, and proportion, and use math formulas.

(1) Volume
(2) Ratio and proportion
(3) Math formulas

Course No: 3ABR56330
Day 4 & 5

Branch Approval: Betty Littyski
Date: 18 Jun 74

## PART II

## INTRODUCTION (10 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (150 MIN)

6a. Solve problems consisting of whole numbers by using addition, subtraction, multiplication, and division.

(1) Addition - sum

(2) Subtraction - remainder

(a) Minuend

(b) Subtrahend

(c) Remainder

(3) Multiplication-product

(4) Division - quotient

36

(a) Quotient

(b) Divisor

(c) Dividend

6b. Solve problems consisting of fractions, by using addition, subtraction, multiplication and division.

(1) Definition of fractions

(2) Types of fractions

(3) Parts of fractions

(4) Rules for solving problems

6c. Solve problems consisting of decimals by using addition, subtraction, multiplication, and division.

(1) Definition of decimals

(2) Reading decimals

(3) Conversion of fractions to decimals

(4) Conversion of decimals to fractions

(5) Rounding off decimals

(6) Rules for solving problems

**APPLICATION:**

Accomplish 2TPT-5111-01 and 2TPT-5111-02

## CONCLUSION (Day 4) (15 Min)

SUMMARY:

STUDY ASSIGNMENT:
SGI-6 Basic Mathematics

## INTRODUCTION (Day 5) (15 Min)

REVIEW:

OVERVIEW:

MOTIVATION:

BODY (240 Min)

**PRESENTATION:**

6d. Solve problems for area, consisting of squares, rectangles and circles

(1) Squares

(2) Rectangles

(3) Circles

6e. Solve problems in volume, ratio, and proportion, and use math formulas.

(1) Volume

(a) Square tank (S x S x H = V)

40

(b) Rectangular tank
($L \times W \times H = V$)

(c) Swimming pool
($L \times W \times AD = V$)

(d) Round tank
($\pi R^2 \times H = V$)

(2) Ratio and proportion

(a) Definition of ratio

(b) Definition of proportion

(c) Rules for solving
problems

(3) Math formulas

(a) $F = 9/5\ C^0 + 32$

(b) $C = 5/9\ (F^0 - 32)$

(c) $$\text{Lbs Cl} = \frac{\text{Gal } H_2O \times 8.3 \times \underline{\quad}\ \text{ppm}}{1{,}000{,}000}$$

APPLICATION:
WB I-6-P1
Basic Math

EVALUATION:
Evaluation by oral, written questions and/or observation of student's performance during lesson. This may be accomplished during lesson for increased effectiveness.

25

## CONCLUSION (15 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:
SG II-1, Basic Chemistry

26

STUDY GUIDES 3ABR56330-I-1, 2, 5, and 6

Department of Civil Engineering Training

17-4

Environmental Support Specialist

# INTRODUCTION TO WATER AND WASTE PROCESSING

October 1974

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

# INTRODUCTION TO WATER AND WASTE PROCESSING

## Days 1 - 5

## Table of Contents

| Project | Title | Page |
|---|---|---|
| I-1 | Orientation | 1 |
| I-2 | Career Field Progression and Training | 16 |
| I-5 | Resources and Work Force Management | 22 |
| I-6 | Basic Mathematics of Water and Waste Processing | 28 |

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This supersedes SG 3ABR56330-I-1 thru - 6, 24 January 1974

## MODIFICATIONS

Pages 1-27 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

29

# BASIC MATHEMATICS OF WATER AND WASTE PROCESSING

## OBJECTIVE

The purpose of this study guide is to acquaint you with the basic mathematics of an environmental support specialist.

## INTRODUCTION

The term, "basic mathematics of an environmental support specialist" applies to the various formulas and mathematical problems encountered in the treatment processes of water production and waste disposal. Determining square feet, cubic feet, area, volume, calculating head, psi, rate of flow, quantity of flow, and gpm are some of the problems you will encounter. This information is presented under the following main topics of this study guide:

- DETERMINING AREA AND VOLUME
- DETERMINING RATIOS AND PROPORTIONS
- DETERMINING HEAD AND POUNDS PER SQUARE INCH

This study guide will not contain all of the information you need to know; therefore, it is recommended that you study additional material on the subject.

## DETERMINING AREA AND VOLUME

As you know, liquids occupy space and have weight. To become a qualified environmental support specialist, you must be able to compute and determine surface areas and volumes of various containers. Of special importance are cylindrical and rectangular-shaped containers.

A circle is a plane figure bounded by a curved line every point of which is equally distant from the center of the figure. (Refer to figure 6.)

The terms associated with a circle are circumference, diameter, and radius. The circumference is the total distance of the curved line that bounds the circle. (Refer to figure 6.)

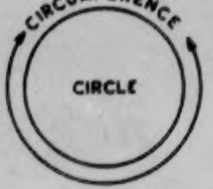

Figure 6. Circumference of a Circle

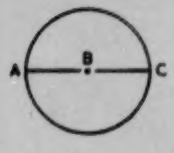

Figure 7. Circle Showing Its Diameter

The diameter of a circle is the distance of a straight line drawn through the center of the circle terminating at both ends on the circumference. In figure 7, the diameter is represented by the straight line from point A to point C with point B being the center of the circle.

The radius of a circle is one-half (1/2) the distance of the diameter. In figure 7, the radius would be the distance from point "A" to point "B" or the distance from point "B" to point "C," either representing one-half of the diameter.

The area of a circle is found by using the formula $A = \pi R^2$. A equals the area of the circle in square units, for example, square inches, square feet, square yards. The Greek letter $\pi$ , pronounced as "pie," is used to represent the relation of the circumference to the diameter of any circle. It has a constant value of 3.14 as a decimal fraction or 22/7 as an improper fraction. $R^2$ equals the radius of the circle multiplied by itself one time. The area represented in the formula by "A" will always be expressed in square units; square feet, square inches, or square yards.

A rectangle is a four-sided plane figure constructed with straight lines connected at right angles to each other. (See figure 8.)

To determine the area of a rectangle, use the formula $A = LW$. A equals the area in square units; square inches, square feet, square yards. L equals the length of the longest side represented in figure 8, by line AB. W equals the distance of the shortest side of the figure represented in figure 8 as line AC.

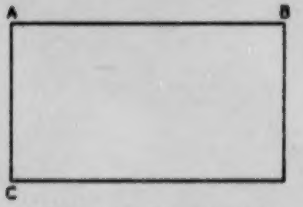

Figure 8. Rectangle

Determining area of a plane figure measures surface only. On objects or figures having depth or height, it is frequently necessary to measure volume or capacity.

To determine the volume of a cylindrical-shaped object, we use the formula: $V = \pi R^2 H$. V equals the volume always expressed in cubic units, whereas area is always expressed in square units. $\pi$ is a constant of 3.14 or 22/7. $R^2$ is the radius of one end of the cylinder multiplied times itself one time. H equals the height of the cylinder. (See figure 9.)

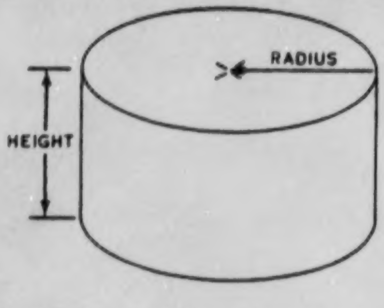

Figure 9. Cylinder Dimensions

To determine the volume of a rectangular object, we use the formula $V = LWH$. V equals the volume of the object expressed in cubic units. L equals the length of the object. W equals the width of the object. H equals the height of the object. (See figure 10.)

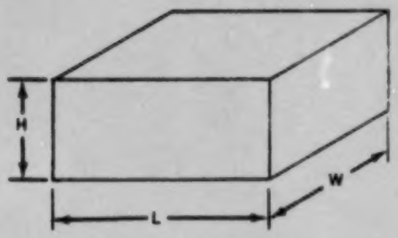

Figure 10. Dimensions of a Rectangle

It is very important to remember that when determining area problems, the answer is always in square units such as square inches, square feet, or square yards. When solving problems on volume, the answer is always expressed in cubic units such as cubic inches, cubic feet, or cubic yards.

## DETERMINING RATIOS AND PROPORTIONS

A ratio shows the relationship between two numbers or things. A proportion shows the relationship between two ratios. Ratios and proportions may be used to solve problems with unknown answers. The formula for determining distance, rate, or time is derived from ratios and proportions.

To determine distance, the formula is $D = RT$. To determine rate, the formula is $R = \frac{D}{T}$. To determine time, the formula is $T = \frac{D}{R}$. In each problem, D equals the distance, R equals the rate, and T equals the time.

For example, if a car were to maintain a constant speed of 40 mph, how far could it go in 2 hours? Forty mph would be the rate, and 2 hours would represent the time. The correct formula to use is $D = RT$ and the correct answer is 80 miles or the distance.

When comparing two ratios in working out a proportion, it is necessary that we talk about the same units. The following relationship may be used: $X : Y :: X : Y$. This is read "X is to Y as X is to Y." To solve this ratio and proportion, the product of the means is equal to the product of the extremes. Now, we can substitute numbers in the place of our letters.

Example: A pump delivers 50 gallons per minute. Find the time required to fill a 500-gallon tank.

1. To solve, write the formula:

   $X : Y :: X : Y$

2. Substitute

   50 gal : 1 minute : : 500 gal : Y minutes

NOTE: The X's must be expressed in the same units, and the Y's must also be expressed in the same units.

3. Application:

$$\overbrace{50\text{ gal} : \underbrace{1\text{ minute} :: 500\text{ gal}}_{\text{Product of Means}} : Y\text{ minutes}}^{\text{Product of the Extremes}}$$

4. 50 Y = 500 gallon minutes.

5. Dividing both sides by 50, we find that Y = 10 minutes.

Another formula frequently employed by water supply specialists is the "Rod Stream" for determining the quantity of water flowing in a channel or stream.

To find the quantity of water in a stream, two things must be known: (1) the average velocity of the stream in feet per minute and (2) the average cross-sectional area in square feet. The following formula is used:

$$Q = 6.4 \text{ X } A \text{ X } V$$

Q = the quantity of flow in gallons per minute

6.4 = a constant factor

A = the average cross section in square feet

V = the velocity of the stream in feet per minute

To use the formula, we must first determine the value for A or the average cross section in square feet. To do this, determine the average width and depth of the stream on a cross-sectional area of the stream large enough to be representative of the whole stream. Use the following formula: A = WD. Where: A = area in square feet. W = average width in feet. D = average depth in feet.

Next, we will have to determine the value for V or the velocity of the stream in feet per minute. To find the velocity, a check is made to determine the number of seconds it takes for a twig to float a measured distance in the same area where the cross-sectional was made. Then, by using a proportion, it is possible to determine the velocity in feet per minute.

As an example, assume that a twig is put into a stream and that it floated 8 feet in 12 seconds.

X : Y : : X : Y
Feet : Sec : : Feet : Sec

$$\underbrace{8 : \underbrace{12 :: X}_{} : 60}_{}$$

12x = 480
x 480/12
x 40 feet per minute

All of the necessary information is now known, so it is possible to use the rod stream formula and determine the quantity of flow of a given stream in gallons per minute.

It should be noted that the rod stream method is a convenient way in the field to measure the rate of flow in a stream. However, it is subject to irregularities in the stream and the accuracy of human measurement, so that the results are not extremely accurate. However, it is possible to obtain a good estimate by this method.

## DETERMINING HEAD AND POUNDS PER SQUARE INCH

Head is the pressure caused by a column of water. It is pressure expressed as feet of water. It is always measured in a vertical direction and is used when talking about pumps.

Discharge head is the vertical distance the pump must lift the water. If a pump must lift the water 10 feet from the ground to the top of a tank, the discharge head is 10 feet. Therefore, the pump will have to operate against a pressure of 10 feet of water.

Suction head is the vertical distance a pump must lift water from the source to the pump. If a pump is drawing water from a stream and the pump is placed 5 feet above the stream, the suction head will be 5 feet.

Friction head is the pressure required to overcome the friction of water flow in a pipe or hose. When water is pumped through a pipe, friction head is the loss caused by internal roughness and skin friction.

Total head is the sum of the discharge head, suction head, and friction head. It is a measure of the total amount of pressure the pump must exert in order to move the water.

Pressure, by definition, is the force per unit area or the force divided by the area. A cubic foot of water exerts a force of 62.4 pounds. This is the weight of the water. To find the pressure, we divide the force by the unit area. If the force is 62.4 pounds and the area is one square foot, the pressure is 62.4 pounds per square foot, abbreviated as 62.4 psf.

The pressure in pounds per square foot is rarely used. Commonly, pressure is expressed in pounds per square inch, abbreviated as psi.

One hundred and forty-four square inches = 1 square foot. Therefore, 62.4 pounds per square foot divided by 144 square inches tells us that a foot of water one inch square exerts .43 psi. Writing a formula, we have psi =feet of water X .43.

For example, what is the pressure at the bottom of a tank ten feet high?

Formula: psi =feet of water X .43

Substituting: psi = 10 X .43

51

Answer: psi =4.3

Pressure is completely independent of the shape of the vessel. Only the vertical height of the water is considered.

Two and three-tenths feet of water exert a pressure of one psi. Therefore, we can determine the depth of water if the psi is known. The formula is: Feet water = psi X 2. 3.

For example, a tank containing water of unkown depth has a pressure gage on the bottom which reads six psi. How many feet of water are in the tank?

Formula: feet water = psi X 2. 3

Substituting: feet water = 6 X 2. 3

Answer: feet water = 13. 8

A cubic foot of water contains 7. 5 gallons of water. Therefore, we can determine gallons of water in a given container by determining the volume in cubic feet of that container. The formula is:

gallons of water = cubic feet X 7. 5

A gallon of water weighs 8. 3 pounds. Therefore, we can determine the weight of a specified volume of water if we first determine the number of gallons. The formula is: pounds of water = gallons of water X 8. 3.

## SUMMARY

In this study guide, we have discussed some of the common mathematical formulas used in water treatment. We discussed how to determine area and volume of containers. We then discussed ratios, proportions, determination of head, and psi. These formulas will greatly aid you in field water treatment.

## QUESTIONS

1. What is the numerical value of $\pi$ ?
2. The surface area of a plane figure is always expressed in what units?
3. What kind of units are used to express volumes?
4. What does the formula $V = \pi R^2H$ determine?
5. From the formula D = RT, explain what each letter symbol represents.
6. Why is the "Rod Stream" formula used?
7. What is "discharge head"?

8. How do we measure "discharge head"?

9. What is meant by psi?

10. What is the psi of a tank containing five feet of water if the tank is two feet in diameter?

11. What does a cubic foot of water weigh?

12. What would be the weight in pounds of 20 gallons of water?

WORKBOOKS

3ABR56631-I-2-P1 and 4-P1 thru 6-P1

17-4

Technical Training

# Environmental Support Specialist

# INTRODUCTION TO ENVIRONMENTAL SUPPORT

September 1975

USAF SCHOOL OF APPLIED AEROSPACE SCIENCES
Department of Civil Engineering Training
Sheppard Air Force Base, Texas

Designed For ATC Course Use

DO NOT USE ON THE JOB

MODIFICATIONS

Pages 1-8 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

# BASIC MATHEMATICS OF ENVIRONMENTAL SUPPORT

## OBJECTIVE

The purpose of this exercise is to aid you in understanding the basic mathematics used in water and waste processing.

## INSTRUCTIONS

Complete each question below. If help is needed, refer to Study Guide 3ABR56631-I-6.

1. Draw a circle inside this square.
2. Draw the diameter of the circle.
3. Draw the radius of the circle perpendicular to the diameter.
4. How much longer is the diameter than the radius? ____________________
5. What decimal number does $\pi$ represent? ____________________
6. Write the formula for finding the area of a circle. ____________________
7. If the circle you drew has a one-inch radius, what is the area of the circle? ____________________
8. If a circle has a two-inch radius, what is the area? ____________________
9. How many times larger is the preceding circle than the one you drew? ________
10. How much larger is a 6-inch pipe than a 3-inch pipe? ____________________
11. If a classroom is 25 feet wide and 30 feet long, how many square feet of floor space are in the room? ____________________
12. A swimming pool is 50 feet long, 20 feet wide, and has an average depth of 5 feet. How many cubic feet of water will it hold? ____________________
13. If there are 7.5 gallons of water in one cubic foot, how many gallons of water will the swimming pool hold? ____________________

14. An air base installed an overhead water storage tank that had a diameter of 16 feet and a tank height of 12 feet. How many gallons of water will the tank hold?

______________________________________________

15. If a pump will deliver 500 gallons of water per minute, how long will it take to fill the preceding overhead storage tank?______________________________.

Hint: X : Y :: X : Y

11-4

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Basic Chemistry (Days 6, 7 and 8)

**LESSON DURATION**

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 18 Hrs | 0 | 18 Hrs |

**POI REFERENCE**

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 7 | 6 June 1975 | 1 |

**STS/CTS REFERENCE**

| NUMBER | DATE |
|---|---|
| STS 563X0 | 28 July 1971 |

**SUPERVISOR APPROVAL**

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**PRECLASS PREPARATION**

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| | None | None | SG II-1<br>WB II-1-P1<br>WB II-1-P2<br>2TPT-5120-03<br>Periodic Chart |

**CRITERION OBJECTIVES AND TEACHING STEPS**

1a. Provided definitions of chemical terms and a list of elements, radicals, and formulas, identify each with its proper term, symbol, formula, or radical.

(1) Chemical terms

1b. Given a list of acids, bases, and salts, identify each by writing its proper formula and from given formulas, determine which ones are acids, bases, and salts.

(1) Acids
(2) Bases
(3) Salts

1c. Provided with a list of symbols and radicals, write formulas for the resulting compounds.
(1) Derive formulas

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LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

1d. Given incomplete chemical equations, write a balanced equation for each reaction.

(1) Definition
(2) Requirements
(3) Types of reactions
(4) Steps in writing balanced equations

☆ GPO: 1972 779-388/24

Course No: 3ABR56330
Days 6, 7, and 8

Branch Approval: Bobby Littlejohn
Date: 18 Jan 75

## PART II

## INTRODUCTION (15 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

## BODY (1060 Min)

**PRESENTATION:**

**1a. Provided definitions of chemical terms and a list of elements, radicals, and formulas, identify each with its proper term, symbol, formula, or radical.**

(1) Chemical terms

(a) Chemistry

(b) Matter

1 States of matter

2 Kinds of matter

(c) Organic matter

(d) Inorganic matter

(e) Substance

(f) Elements - calcium, magnesium, sodium, hydrogen, iron, manganese, oxygen, chlorine, fluorine, and aluminum

1 Proper term

2 Symbol

3 Atomic number

4 Atomic weight

5 Valence

6 Equivalent weight

- a Formula
  - 1 Element
  - 2 Radical
  - 3 Compound

(g) Atom

- 1 Definition
- 2 Structure
  - a Proton
  - b Neutron
  - c Electron

(h) Ion

1 Definition

2 Cation

3 Anion

4 Radicals - $CO_3$, $HCO_3$, OH, $PO_4$, $SO_4$, $NO_3$, $NH_4$, and $OCl$

(i) Compound

1 Definition

2 Electro-valent bonding

3 Co-valent bonding

4 Formula

5 Molecule

6 Molecular weight

APPLICATION:

Have students complete the first three units of WB 3ABR56330-II-1-P1.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (Day 6)

SUMMARY:

Briefly summarize main points of lesson.

STUDY ASSIGNMENT:

1. Accomplish 2TPT-5120-03
2. Read SG 3ABR56330-II-1, pages
3 through 5.

INTRODUCTION (Day 7)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

OVERVIEW:

MOTIVATION:

PRESENTATION:

1a. (Continued)

(j) Ionization

1 Definition

2 Demonstrate

(k) Metal

- 1 Definition
- 2 Characteristics
- 3 Elements and alloys classed as metals

(l) Non-metals

- 1 Definition
- 2 Characteristics
- 3 Elements classed as non-metals

(m) Solution

1 Definition

2 Examples

a Solid in a liquid

b Liquid in a liquid

c Gas in a liquid

3 Solvent

4 Solute

5 Concentrated solution

6 Dilute solution

7 Saturated solution

8 Super saturated solution

9 Standard solution

10 Normal solution

(n) Specific gravity

1 Definition

2 Examples

1b. Given a list of acids, bases, and salts, identify each by writing its proper formula and from given formulas, determine which ones are acids, bases, and salts.

(1) Acids-sulfuric, hydrochloric, carbonic, and silicic

(a) Proper terms

1 Characteristics

2 Concentrated

3 Dilute

4 Strong

5 Weak

(b) Symbols and radicals (formulas)

(2) Bases - sodium hydroxide, ammonium hydroxide, calcium hydroxide, and magnesium hydroxide

(a) Proper terms

1 Characteristics

2 Concentration

(b) Symbols and radicals

(3) Salts - calcium carbonate, calcium biocarbonate, sodium chloride, magnesium sulphate, sodium carbonate, magnesium carbonate, calcium sulphate, and calcium chloride

(a) Proper terms

(b) Symbols and radicals (formulas)

APPLICATION:

1. Have students accomplish WB 3ABR56330-II-1-P1

2. Provided with a list of formulas of common acids, bases or salts, select the formulas which represent acids and copy them in one column. Next, select the formulas which represent bases and copy them in a second column. Then, select the formulas representing salts and copy them in a third column.

## CONCLUSION (Day 7)

SUMMARY:

Briefly summarize main points of lesson.

STUDY ASSIGNMENT:

Read SG 3ABR56330-II-1, pages 5 through 14, and answer questions on page 15.

## INTRODUCTION (Day 8)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT:

REVIEW:

ATTENTION:

OVERVIEW:

(e) Balance electrical charges of cation and anion - write subscripts for cation and anion ONLY if quantity required is two or more units. Be sure to enclose radicals in parenthesis when more than one unit is required

(2) Explain significance of the subscripts

APPLICATION:

Provided with a list of 7 common cations and 7 common anions, combine each cation with the 7 anions to form 49 formulas of compounds which occur as common water impurities, or as common water treatment chemicals.

PRESENTATION:

1d. Given incomplete chemical equations, write the balanced equation for each reaction.

(1) Definition of the term "Chemical Equation"

(2) Requirements for a balanced chemical equation

(3) Common types of chemical reactions

  (a) Combination

  (b) Decomposition

  (c) Displacement

  (d) Double displacement

  (e) Oxidation-reduction

(4) Steps involved in writing balanced chemical equation. (Be sure to explain the significance of the coefficients)

(a) Write the formulas for the two reactants, followed by an arrow

(b) Indicate the valence for all elements or radicals contained in the two reactants

(c) Write the formulas for the products formed by the chemical reaction

(d) Indicate the valence for all elements or radicals contained in the products

(f) Check to see if the (+) and (-) valences of the of the cations and anions of the two products are balanced

(g) When required, balance the (+) and (-) valences of the cations and anions of the two products by writing the proper subscripts

(h) Where required, write the correct "coefficient" for the compounds involved in the chemical equation

APPLICATION:

Have students complete the portions of WB 3ABR56330-II-1-P1 pertaining to "Solving For Chemical Equations"

Additional practice - time permitting

$CO_2 + H_20 =$

$H_2CO_3 + CaCO_3 =$

$H_2SO_4 + CaCO_3 =$

$Na_2CO_3 + CaSO_4 =$

$Na_2CO_3 + MgSO_4 =$

$Ca(OH)_2 = MgCO_3 =$

$C1_2 + HOH =$

$Ca(HCO_3)_2$ + heat =

$HC1 + NaOH =$

59

APPLICATION:

Have students complete WB 3ABR56330-II-1-P2.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

## CONCLUSION (5 Min)

SUMMARY:

Briefly summarize the main points of lesson.

REMOTIVATION:

STUDY ASSIGNMENT:

1. Review SG 3ABR56330-II-1
2. Read SG 3ABR56330-II-2 and -3 and answer questions at back of each study guide.

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Air Force Water Requirements (Day 9)

**LESSON DURATION**

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 2 Hrs | 0 | 2 Hrs |

**POI REFERENCE**

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 8 | 6 June 1975 | 2 |

**STS/CTS REFERENCE**

| NUMBER | DATE |
|---|---|
| STS 563X0 | 28 July 1971 |

**SUPERVISOR APPROVAL**

| SIGNATURE | DATE | SIGNATURE | DATE |
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**PRECLASS PREPARATION**

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| None | None | None | SG II-2<br>WB II-2-P1 |

**CRITERION OBJECTIVES AND TEACHING STEPS**

2a. Using related information, list the Air Force water requirements for domestic, fire, and industrial water.

(1) Domestic
(2) Industrial
(3) Fire

2b. Given related information, list the conservation measures of water.

(1) Purpose
(2) Recognition of water waste
(3) Conservation practices

ATC FORM AUG 72 770

Course: 3ABR56330
Day 9

Branch Approval: Kibby G Littlejohn
Date: 20 Jan 75

## PART II

## INTRODUCTION (15 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

## BODY (1 Hr 40 Min)

**PRESENTATION:**

2a. Using related information, list the Air Force water requirements for domestic, fire, and industrial water.

(1) Domestic

(a) Home usage

(b) Watering lawns

(c) Swimming pools

(2) Industrial

(a) Domestic water that needs additional treatment before using in equipment

(b) Treatment normally includes distilling, demineralizing, adding corrosion prevention compounds, treating to prevent algae

(c) Industrial water is used in boilers, base laundry, photo lab, jet engines, air conditioning cooling towers

(3) Fire

(a) Fire plugs connected to domestic mains

(b) Domestic supply must be capable of supplying large quantities

2b. Given related information, list the conservation measures of water.

(1) Purpose

- (a) Wasted water is wasted money
- (b) Added load on water plant and sewage plant

(2) Recognition of water waste

- (a) Continuously running or leaking faucets
- (b) Excess watering of lawns

(3) Conservation practices

(a) Programs and posters for conservation of water usage

(b) Lawn watering limited to certain times of day and certain days of month

(c) Conservation monitor who monitors the conservation program

APPLICATION:

Accomplish WB 3ABR56330-II-2-P1

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

## CONCLUSION (5 Min)

**SUMMARY:**

**REMOTIVATION:**

**STUDY ASSIGNMENT:** None

67

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Sources and Characteristics of Water (Day 9)

LESSON DURATION

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 4 Hrs | 0 | 4 Hrs |

POI REFERENCE

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 8 | 6 June 1975 | 3 |

STS/CTS REFERENCE

| NUMBER | DATE |
|---|---|
| STS 563X0 | 28 July 1971 |

SUPERVISOR APPROVAL

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
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PRECLASS PREPARATION

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| None | None | None | SG II-3<br>WB II-3-P1 |

CRITERION OBJECTIVES AND TEACHING STEPS

3a. Given related information, list the common sources of water.

(1) Ground
(2) Surface

3b. Given the types of impurities that may be found in water and the sources of water, identify the impurities that are normally found in high or low amounts in each source by comparison.

(1) Impurities found in water
(2) Characteristics impurities give water
(3) The amount of impurities in ground water as compared to surface water

ATC FORM AUG 72 770

Course No: 3ABR56330
Day 9

Branch Approval: Bobby G. Littlejohn
Date: 20 Jun 75

## PART II

## INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

PRESENTATION:

3a. Given related information, list the common sources of water.

- (1) Ground
  - (a) Wells
  - (b) Springs
- (2) Surface
  - (a) Rivers
  - (b) Lakes
  - (c) Oceans

3b. Given the types of impurities that may be found in water and the sources of water, identify the impurities that are normally found in high or low amounts in each sources by comparison.

(1) Impurities found in water

(a) Suspended solids

(b) Dissolved solids

(c) Dissolved gases

(2) Characteristics impurities give water

(a) Turbidity

(b) Hardness

(c) Alkalinity

(e) Odor

(f) Color

(g) pH

1 pH scale

2 pH indication

a Acid

b Alkaline

(3) The amount of impurities in ground water as compared to surface water

(a) Total dissolved solids

1 High in ground water

2 Low in surface water

(b) Suspended solids

1 High in surface water

2 Low in ground water

(c) Dissolved gases

1 High in surface water

2 Low in ground water

(d) Biological organisms

1 High in surface water

3c. Given a list of water characteristics, write the impurities that will cause each characteristic.

(1) Dissolved solids

(a) Hardness

1 Calcium

2 Magnesium

3 Iron

4 Manganese

5 Silicon

(b) Alkalinity

1 Hydroxide

2 Carbonate

3 Bicarbonate

(2) Suspended solids

(a) Turbidity

1 Sand

2 Silt

3 Clay

4 Mud

(b) Taste, odor, color

1 Bacteria

2 Algae

3 Vegetable matter

4 Iron

5 Manganese

6 Industrial waste

(3) Dissolved gases

(a) Oxygen

(b) Carbon dioxide

76

(4) Biological organisms

APPLICATION:

1. Have students list the common sources of water
2. Have students complete WB 3ABR56330-II-3-P1

EVALUATION:
Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (10 Min)

SUMMARY:

STUDY ASSIGNMENT:
Read study guide 3ABR56330-II-4-5-6, pages 30 thru 43 and answer questions at the end of each chapter.

77

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Laboratory Safety (Day 10)

LESSON DURATION

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 1 Hr | 0 | 1 Hr |

POI REFERENCE

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 9 | 6 June 1975 | 4 |

STS/CTS REFERENCE

| NUMBER | DATE |
|---|---|
| STS 563X0 | 28 July 1971 |

SUPERVISOR APPROVAL

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
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PRECLASS PREPARATION

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| Laboratory Testing Equipment<br>Laboratory Safety Equipment | None | None | SG II-4<br>WB II-4-P1<br>TVS-2410 |

CRITERION OBJECTIVES AND TEACHING STEPS

4a. Following oral instructions, apply precautions when handling reagents and chemicals.

(1) Film TVS-2410, Safety in the Chemical Laboratory
(2) Laboratory safety rules
(3) Laboratory safety equipment

4b. Given actual laboratory equipment, determine proper selection, care and use of the equipment during water and wastewater analysis.

(1) Identifying laboratory test equipment
(2) Care of test equipment
(3) Application of test equipment

ATC FORM AUG 73 770

Course No: 3ABR56330
Day 10

Branch Approval: Bobby G. Littlejohn
Date: 28 Jun 75

## PART II

## INTRODUCTION (5 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (50 Min)

PRESENTATION:

4a. Following oral instructions, apply precautions when handling reagents and chemical.

(1) Film TVS-2410, Safety in the Chemical Laboratory

(a) Introduce film

(b) Tell students what to look for in the film

(c) Discuss film after showing

(2) Laboratory safety rules

(a) Remove jewelry

(b) Do not waste chemicals

(c) Smell chemicals slowly

(d) Never mix chemicals at random

(e) Use protective equipment as required

(f) Do not use cracked or broken glassware

(g) Keep work area clean

(h) Label all bottles, reagents and samples

(i) Do not heat closed containers

(j) If your skin burns or feels slick, wash it in plenty of cool water

(k) Add chemicals to water - never water to strong chemicals

(3) Laboratory safety equipment

(a) Rubber apron

(b) Face shield or goggles

(c) Rubber gloves

(d) Asbestos gloves

(e) Tongs

(f) Deluge shower

(g) Rubber floor mats

(h) Eye wash

(i) Exhaust fan or hood

(j) Precautions when handling chemicals

  1 Strong or dangerous chemicals should not be stored above eye level

  2 Open bottle and lay stopper upside down

  3 Pour chemicals slowly

4 Avoid breathing fumes

4b. Given actual laboratory equipment, determine proper selection, care and use of the equipment during water and wastewater analysis.

(1) Identifying laboratory test equipment

(2) Care of test equipment

(3) Application of test equipment

APPLICATION:

Accomplish WB 3ABR56330-II-4-P1.

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

## CONCLUSION (5 Min)

SUMMARY:

Briefly summarize main points of lesson.

REMOTIVATION:

Reemphasize the importance of todays lesson.

STUDY ASSIGNMENT: None

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Collecting and Labeling Water and Wastewater Samples (Day 10)

LESSON DURATION

| | | |
|---|---|---|
| CLASSROOM/LABORATORY<br>2 Hrs | COMPLEMENTARY<br>0 | TOTAL<br>2 Hrs |

POI REFERENCE

| | | |
|---|---|---|
| PAGE NUMBER<br>10 | PAGE DATE<br>6 June 1975 | PARAGRAPH<br>5 |

STS/CTS REFERENCE

| | |
|---|---|
| NUMBER<br>STS 563X0 | DATE<br>28 July 1971 |

SUPERVISOR APPROVAL

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
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PRECLASS PREPARATION

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| Water Sample Bottle<br>Wastewater Sample Bottle | None | None | SG II-5<br>WB II-5-P1<br>563X0 Career Ladder Laboratory Manual - All Crses<br>Schematic of Sewage Plant |

CRITERION OBJECTIVES AND TEACHING STEPS

5a. Following written instructions, collect and label a water sample for testing.

(1) Purpose of water sampling
(2) Procedures for collecting water samples
(3) Collect and label water samples

5b. Following written instructions, collect and label a wastewater sample for testing.

(1) Purpose of wastewater sampling
(2) Types of samples
(3) Procedures for collecting wastewater samples
(4) Collect and label wastewater samples

ATC FORM AUG 72 770

Course No: 3ABR56330 Branch Approval: Bobby G Littlejohn
Day 10 Date: 20 Jun 75

## PART II

### INTRODUCTION (5 Min)

CHECK PREVIOUS DAYS STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

## BODY (110 Min)

PRESENTATION:

5a. Following written instructions, collect and label a water sample for testing.

(1) Purpose of sampling

(a) To plan and control water treatment

(b) To insure quality control

(c) Sampling is needed of raw water at its source and also at the completion of each phase of treatment.

(d) Sampling is needed for performing chemical analysis and bacteriological test

(2) Procedures for collecting water samples

(a) Sample containers—

1 Container should be clean with no residue, mud or scale in it.

2 Container should be leak proof and corrosion proof.

(b) Sampling containers-for bacteria testing.

1 Glass stoppered bottle must be used

2 Bottle, stopper, and sample must NOT be contaminated from dust or handling

(c) Raw water (ground) samples are taken at or near source.

1 Take sample after operating pump long enough to flush out line and to stabilize the well.

2 Rinse sample bottle with water to be tested, then fill to overflow.

3 Cap or cork immediately but do not force the cap in as bottle may break.

(d) Raw water (surface)

1 Sample as near the intake depth and location as possible.

2 Sample may be taken at pump discharge side.

(e) Treated water sampling

1 Sample must be representative of treatment process.

2 Several samples may be necessary to get representative sample.

3 Let the water tap run long enough to get an accurate main line supply.

(f) Dissolved gas samples

1 Sample must not be aerated while being obtained.

2 Use rubber hose or tap extension to reach bottom of bottle.

3 Fill bottle slowly

4 Test for dissolved gas immediately.

(g) Labeling water samples

1 Labels are not standard

2 Some labels are printed and you fill out the required information such as; collectors name, office and phone number, date sample taken, temperature of sample, type of analysis needed

(3) Collect and label water sample

5b. Following written instructions, collect and label a waste water sample for testing.

(1) Purpose of waste water sampling

(a) Check and monitor plant operation efficiently

(b) Check effuent for quality standard

(c) Determine need for
increased plant facility

(2) Types of samples

(a) Grab (influent-effluent)

1 pH

2 Settleable solids

3 Chlorine residual

4 Chlorine demand

5 Relative stability

(b) Composite sample (influent,
effluent, and digester)

1 BOD

2 Suspended solids

3 Total solids

4 Volatile solids

(c) Sampling point

(d) Safety Precautions

(3) Procedures for collecting waste water samples

(a) Collect free flowing sewage

(b) Prevent aeration (D.O. sample)

(c) Collect sample with sampler facing away from flow.

(d) Rinse sampler with waste sample

(e) Take sample under surface

(4) Collect and label waste water sample

APPLICATION:

Accomplish WB 3ABR56330-II-5-P1

EVALUATION:

Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (5 Min)

SUMMARY:

Briefly summarize main points of lesson.

REMOTIVATION:

Reemphasize the importance of todays lesson.

STUDY ASSIGNMENT:

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Water Analysis (Days 10, 11, 12, and 13)

LESSON DURATION

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 18 Hrs | 0 | 18 Hrs |

POI REFERENCE

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 11 | 6 June 1975 | 6 |

STS/CTS REFERENCE

| NUMBER | DATE |
|---|---|
| 563X0 | 28 July 1971 |

SUPERVISOR APPROVAL

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
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PRECLASS PREPARATION

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| Laboratory Equipment<br>Direct Reading Colorimeter<br>Water Analysis Kit<br>Electric Lab Stirrer | None | None | SG II-6<br>WB II-6-P1<br>WB II-6-P2<br>563X0 Career Ladder Laboratory Manual, All Courses<br>TF 6197 a, b, and d |

CRITERION OBJECTIVES AND TEACHING STEPS

6a. Following written instructions, observing safety precautions, working as a team, and using the colorimetric testing method, determine the amount of chlorine, turbidity, color, fluorides, iron, sulfate, and pH in prepared water samples within ± 15 percent of that present.

(1) Purpose of water analysis
(2) Methods of analyzing water
(3) Source of chlorine, turbidity, iron, fluorides, color, and sulfate in water
(4) Equipment used to perform the tests
(5) Safety precautions
(6) Film TF 6197a, Methods of Water Testing, Color Comparison
(7) Test procedures

ATC FORM AUG 72 770

## LESSON PLAN (Part I, General) CONTINUATION SHEET

CRITERION OBJECTIVES AND TEACHING STEPS (Continued)

6b. Following written instructions, observing safety precautions, working as a team, and using the volumetric testing method, determine the amount of hardness, alkalinity, chlorides, and carbon dioxide in prepared water samples within ± 15 percent of that present.

(1) Ion causing hardness and alkalinity
(2) Sources of chlorides and carbon dioxide
(3) Equipment used to perform the tests
(4) Safety precautions
(5) Film TF-6197b, Methods of Water Testing, Volumetric Titration
(6) Testing procedures

6c. Using a laboratory thermometer and following written instructions, measure the temperature of a water sample to ± $1^{0}$.

(1) Procedure for collecting the sample
(2) Reading the thermometer
(3) Fahrenheit and centigrade conversion
(4) Testing procedures

6d. Following written instructions, observing safety precautions, working as a team, and using an electric meter, determine the pH of a water sample to ± 0.5 pH unit.

(1) pH characteristics
(2) pH scale
(3) Use of pH meter
(4) Film TF 6197d, Methods of Water Testing, Electric Meter

6e. Given related information, state the method used to perform the phosphate and silica test.

(1) Sources of phosphates and silicas
(2) Method of testing for phosphates and silicas

6f. Using test equipment and written instructions, perform the jar test to determine minimum chemical dosage.

(1) Chemical used
(2) Procedure for performing test
(3) Calculating results

Course No: 3ABR56330 Branch Approval: Bobby Littleyest
Day 10, 11, 12, 13 Date: 24 Jun 75

## PART II

## INTRODUCTION (15 Min)

CHECK PREVIOUS DAY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

## BODY (17.5 Hrs)

PRESENTATION:

6a. Following written instructions, observing safety precautions, working as a team, and using the colorimetric testing method, determine the amount of chlorine, turbidity, color, fluorides, iron, sulfate, and pH in prepared water samples within ± 15 percent of that present.

(1) Purpose of water analysis

(a) To determine the quality of the sample.

(b) To periodically determine the purity and mineral content of domestic water.

(c) To determine the quality of water for industrial use.

(2) Methods of analyzing water.

(a) The gravimetric water analysis is performed by separating a substance from the water sample, weighing the substance, and calculating the proportion by weight with respect to the total sample.

(b) The volumetric water analysis is performed by adding to a measured portion of a water sample the exact volume of a standard strength chemical solution required to bring about a specific change. The addition of a measured volume of a standard strength solution to a water sample is called titration.

(c) The colorimetric water analysis is performed by comparing the colors produced in a water sample with those of a prepared color standard.

(d) The conductance water analysis (electric meter) is performed by the immersion of electrodes in a water sample.

(e) Expression of test results

1 ppm

2 gpg

3 mg/l

4 ml/l

(3) Source of chlorine, turbidity, iron, fluorides, color, and sulfate in water.

(a) Chlorine-water treatment

(b) Turbidity-suspended matter

(c) Iron-the soil iron salts

(d) Fluorides-fluoride mineral in soil

(e) Color

1 True color-dissolved matter

2 Apparent color-suspended matter

(f) Sulfates-sulfate mineral in the soil

(4) Equipment used to perform the tests

(a) Hach Kit

1 Sulfate

2 Fluoride

3 Iron

4 Color

5 Turbidity

(b) Hellige color comparator kit-chlorine

(c) Taylor color comparator kit-pH

(5) Safety Precautions

## CONCLUSION DAY (10)

SUMMARY:

Briefly summarize the main points of the lesson

STUDY ASSIGNMENT:

Read the testing procedures for color, chlorine, fluorides, iron, sulfate, turbidity, and pH in the Career Ladder 563x0 Laboratory Manual.

## INTRODUCTION DAY (11)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

PRESENTATION:

6a. Continued

(6) Film TF 6197a, Methods of Water Testing, Color Comparison

(a) Introduce film

(b) Tell student what to look for in film

(c) Discuss film after showing

(7) Test procedures

(a) Follow written instructions

(b) Cleaning procedures

(c) Use of equipment

(d) Expression of test results.

APPLICATION

1. Assign student to test station

2. Have students follow test instructions and perform the color, turbidity, iron, sulfate, fluoride, chlorine, and pH tests.

PRESENTATION:

6b. Following written instructions, observing safety precautions, working as a team, and using volumetric testing method, determine the amount of hardness, alkalinity, chlorides, and carbon dioxide in prepared water samples within ± 15 percent of that present.

(1) Ion causing hardness and alkalinity

(a) Hardness

1 Calcium

2 Magnesium

(b) Ion causing alkalinity

1 Hydroxide

2 Bicarbonate

3 Carbonate

(2) Sources of chlorides and carbon dioxide

(a) Soil-Chlorides

(b) Break down of bicarbonates

(3) Equipment used to perform the tests

(a) Burette

(b) Graduated cylinder

(c) Stirring rod

(d) Casserole or flask

(e) Chemical scoop

(4) Safety precautions

(a) Keep work area clean and uncluttered

(b) Wear rubber apron

(c) Clean up spillage immediately

(d) Do not let chemicals come in contact with your skin

(e) Follow the written instructions when performing test

## CONCLUSION DAY (11)

**SUMMARY:**
Briefly summarize the main points of the lesson.

**STUDY ASSIGNMENT:**

Read the testing procedures for hardness, alkalinity, chlorides, and carbon dioxide in Career Ladder 563x0 Laboratory Manual.

## INTRODUCTION DAY (12)

**CHECK PREVIOUS DAY'S STUDY ASSIGNMENT**

**REVIEW:**

**ATTENTION:**

**OVERVIEW:**

**MOTIVATION:**

PRESENTATION:

6b. Continued

(5) Film TF-6197b, Methods of Water Testing, Volumetric Titration.

(a) Introduce film

(b) Tell students what to look for in the film

(c) Discuss the film after showing

(6) Testing procedures

(a) Follow test instructions

(b) Reading graduated cylinder

(c) Twenty drops per milliter

(d) Rate of titration

(e) Importance of mixing sample and reagent during titration

(f) Observe safety precautions

(g) Cleaning procedure

APPLICATION:

1. Assign student to test station

2. Have students follow test instructions to perform hardness, alkalinity, chloride, and carbon dioxide tests

3. Have students accomplish W.B. 3ABR56330-II-6-P1 and 3ABR56330-II-6-P2

PRESENTATION:

6c. Using a laboratory thermometer and following written instructions, measure the temperature of a water sample to ± 1°.

(1) Procedure for collecting the sample.

(2) Reading the thermometer

(3) Fahrenheit and centigrade conversion.

(4) Testing procedures

6d. Following written instructions observing safety precautions, working as a team, and using an electric meter, determine the pH of a water sample to ± 0.5 pH unit.

(1) pH characteristics

(a) Hydrogen ion concentration

(b) Degree of acidity and alkalinity of water

(2) pH scale

(3) Use of a pH meter

(4) Film TF 6197d, Methods of Water Testing, Electric Meter.

(a) Introduce the film

(b) Tell students what to look for in film

(c) Discuss film after showing.

APPLICATION:

Have student follow test instructions in workbook to perform the electric pH test.

CONCLUSION DAY (12)

SUMMARY:

Briefly summarize the main point of the lesson.

STUDY ASSIGNMENT:

1. Read the principles and procedures for performing the phosphate, silica, and jar test in laboratory manual.

2. Read SG-3ABR56330-II-7, Waste Water Analysis.

3. Answer questions in back of SG-3ABR56330-II-6

## INTRODUCTION DAY (13)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

PRESENTATION:

6e. Given related information, state the method used to perform the phosphate and silica test.

(1) Sources of phosphates and silicas

(a) Phosphates

1 Mineral in soil

2 Water treatment

(b) Silica-sand dissolved in water

(2) Method of testing for phosphates and silica

(a) Phosphates

1 Colorimetric

2 Hach Kit equipment

3 Orthophosphates

4 Polyphosphates

(b) Silica

1 Colorimetric

2 Taylor comparator equipment

3 Expression of test results.

6f. Using test equipment and written instructions, perform the jar test to determine minimum chemical dosage.

(1) Chemical used

(a) Ferric chloride coagulant-
10 grams per liter

(b) Soda ash-pH adjuster-
10 grams per liter

(2) Procedure for performing test

(3) Calculating results

APPLICATION:

Have students follow instructions in laboratory manual to perform the jar test.

EVALUATION:
Evaluate by oral, written questions, and/or observation of students performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

## CONCLUSION (15 Min)

**SUMMARY:**

**REMOTIVATION:**

**STUDY ASSIGNMENT:**

## LESSON PLAN ( Part I, General)

| | |
|---|---|
| APPROVAL OFFICE AND DATE<br>TCETC/17June75 | INSTRUCTOR |
| COURSE NUMBER<br>3ABR56330 | COURSE TITLE<br>Environmental Support Specialist |
| BLOCK NUMBER<br>II | BLOCK TITLE<br>Water and Wastewater Analysis |

LESSON TITLE
Wastewater Analysis (Days 13, 14, and 15)

**LESSON DURATION**

| CLASSROOM/LABORATORY | COMPLEMENTARY | TOTAL |
|---|---|---|
| 13.5 Hrs | 2 Hrs | 15.5 Hrs |

**POI REFERENCE**

| PAGE NUMBER | PAGE DATE | PARAGRAPH |
|---|---|---|
| 12 | 6 June 1975 | 7 |

**STS/CTS REFERENCE**

| NUMBER | DATE |
|---|---|
| 563X0 | 28 July 1971 |

**SUPERVISOR APPROVAL**

| SIGNATURE | DATE | SIGNATURE | DATE |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**PRECLASS PREPARATION**

| EQUIPMENT LOCATED IN LABORATORY | EQUIPMENT FROM SUPPLY | CLASSIFIED MATERIAL | GRAPHIC AIDS AND UNCLASSIFIED MATERIAL |
|---|---|---|---|
| Laboratory Equipment<br>Prepared Wastewater Samples<br>Drying Oven<br>Muffle Furnace<br>Analytical Balance<br>Electric pH Meter<br>Water Analysis Kit | None | None | SG II-7<br>WB II-7-P1<br>AFM 85-14<br>563X0, Career Ladder Laboratory Manual, All Courses<br>TF 6197c |

**CRITERION OBJECTIVES AND TEACHING STEPS**

7a. Following written instructions, using laboratory equipment, observing safety precautions, and working as a team, perform a dissolved oxygen test on a prepared water sample to ± 2 ppm.

(1) Purpose of test
(2) Procedure for performing test
(3) Proper use of test equipment

7b. Using an Imhoff cone and written instructions, working as a team and observing safety precautions, determine the volume of settleable solids in a wastewater sample to ± 5 ml/l.

(1) Proper use of equipment

ATC FORM AUG 72 770

(2) Procedure for performing the test
(3) Expression of test results

7c. Using the gravimetric method of testing and following written instructions, working as a team and observing safety precautions, determine the amount of suspended solids, total solids, and volatile solids in a prepared wastewater sample within ± 15 percent of that present.

(1) Steps in the test
(2) Proper use of test equipment
(3) Safety precautions
(4) Calculating test results

7d. Using the test results from the total and suspended solids tests, compute the amount of dissolved solids in a wastewater sample.

(1) Formula for calculation
(2) Expression of test results

7e. Using laboratory test equipment and following written instructions, working as a team and observing safety precautions, correctly prepare the samples needed to determine biochemical oxygen demand and relative stability of wastewater.

(1) Safety precautions
(2) Purpose of tests
(3) Procedure for performing tests

Course No: 3ABR56330
Day: 13, 14, & 15

Branch Approval: Bobby J. Littlefield
Date: 25 June 1976

## PART II

## INTRODUCTION (10 Min)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

BODY (13 Hrs. 10 Min)

PRESENTATION:

7a. Following written instructions, using laboratory equipment, observing safety precautions, and working as a team, perform a dissolved oxygen test on a prepared water sample to ± 2 ppm.

(1) Purpose of test

(2) Procedure for performing the test

(a) Collect a wastewater sample.

(b) Dilute the sample to a desired strength

(c) Siphon 2 BOD bottles full of the prepared sample.

(d) Place one BOD bottle of the sample in incubator.

   (e) Perform a dissolved oxygen test on the other BOD bottle sample.

   (f) Use written instructions for preparation of sample and performance of the dissolved oxygen test.

(3) Proper use of test equipment

   (a) Plunger type mixing rod

   (b) Siphon tube

   (c) Pipettes

   (d) Suction bulb

   (e) BOD bottle

   (f) Burette

(g) Observe safety

**APPLICATION:**

Have student prepare a BOD sample and follow written instructions to perform a dissolved oxygen test on the prepared sample.

## CONCLUSION DAY (13)

**SUMMARY:**

Briefly summarize the main points of lesson.

**STUDY ASSIGNMENT:**

Read in laboratory manual the procedures and principles for performing the settleable, suspended, and total solids tests.

## INTRODUCTION DAY (14)

**CHECK PREVIOUS DAY'S STUDY ASSIGNMENT**

**REVIEW:**

**ATTENTION:**

OVERVIEW:

MOTIVATION:

PRESENTATION:

7b. Using an Imhoff cone and written instructions, working as a team and observing safety precautions, determine the volume of settleable solids in a waste water sample to ± 5 ml/l.

(1) Proper use of equipment

(a) Imhoff cone

(b) Imhoff cone stand

(2) Procedure for performing the test

(3) Expression of test results-ml/l.

7c. Using the gravimetric method of testing and following written instructions, working as a team and observing safety precautions, determine the amount of suspended solids, total solids, and volatile solids in a prepared wastewater sample within ± 15 percent of that present.

(1) Steps in the test

(2) Proper use of test equipment

(a) Filter crucible

(b) Suction apparatus

(c) Evaporating dish

(d) Steam bath

(e) Drying oven

(f) Tongs

(g) Dessicator

(h) Analytical balance

(3) Safety precautions

(a) Open flame

(b) Boiling

(c) Wastewater

(d) Oven

(e) Vacuum pump

APPLICATION:

SUMMARY:

Briefly summarize the main points of the lesson.

STUDY ASSIGNMENT:

1. Answer questions in back of SG 3ABR56330-II-7

2. Read the instructions for performing the BOD test and for calculating the dissolved solids in a wastewater sample.

## INTRODUCTION DAY (15)

CHECK PREVIOUS DAY'S STUDY ASSIGNMENT

REVIEW:

ATTENTION:

OVERVIEW:

MOTIVATION:

PRESENTATION:

7c. (4) Calculating test results.

(a) Formula

(b) Recording test results

APPLICATION:

1. Have students perform the volatile solids test.
2. Have students to calculate the test results in ppm.

PRESENTATION:

7d. Using the test results from the total and suspended solids tests, compute the amount of dissolved solids in a wastewater sample.

(1) Formula for calculation

(2) Expression of test results

7e. Using laboratory equipment and following written instructions, working as a team and observing safety precautions, correctly prepare the samples needed to determine the biochemical oxygen demand and relative stability of wastewater.

(1) Safety precautions

(2) Purpose of tests

(3) Procedures for performing tests

APPLICATION:

1. Have students calculate the amount of dissolved solids from the total solids and suspended solids test results

2. Have student follow written instructions to prepare wastewater samples for the BOD and relative stability tests and perform a dissolved oxygen test for BOD calculation.

EVALUATION:
Evaluate by oral, written questions, and/or observation of student's performance during lesson. This may be accomplished at any time during lesson for increased effectiveness.

CONCLUSION (15 Min)

SUMMARY:

REMOTIVATION:

STUDY ASSIGNMENT:

STUDY GUIDE 3ABR56330-II-1 thru 7

Department of Civil Engineering Training

174

Engineer Environmental Support Specialist

# WATER AND WASTEWATER ANALYSIS

February 1972

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

# WATER AND WASTE WATER ANALYSIS

## TABLE OF CONTENTS

| PROJECT | TITLE | PAGE |
|---|---|---|
| II-1 | Basic Chemistry | 1 |
| II-2 | Air Force Water Requirements | 17 |
| II-3 | Types and Characteristics of Water Sources | 22 |
| II-4 | Laboratory Safety | 30 |
| II-5 | Collecting and Labeling Water and Waste Samples | 33 |
| II-6 | Water Analysis | 42 |
| II-7 | Wastewater Analysis | 44 |

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138

# BASIC CHEMISTRY

## OBJECTIVE

The purpose of this study guide is to aid you in understanding basic chemistry.

## INTRODUCTION

To fully and effectively treat water for drinking purposes or for industrial use, an understanding of basic chemistry is desirable. Since most water treatment processes require chemical treatment, an understanding of chemistry provides you with an insight into the treatment process. The study of chemistry raises many different and challenging problems. Information on this subject is presented under the following main topics in this study guide.

- MATTER
- CHEMICAL TERMS
- THEORY OF IONIZATION
- ACIDS
- BASES
- SALTS
- CONCENTRATIONS
- TYPES OF CHEMICAL REACTIONS
- BALANCING CHEMICAL EQUATIONS
- EXPRESSION OF TEST RESULTS

# MATTER

Matter is anything that occupies space and has weight. This includes people, oxygen, water, and almost anything you can name. Even though gases are light enough to rise, they do have weight and occupy space.

A person's shadow occupies space because it has width and height; however, it does not have weight and, therefore, cannot be matter.

The three states of matter are solids, liquids and gases. Solids are made of molecules that stick together very tightly. The molecules of a liquid stick together, but not very tightly. Gas molecules do not stick together at all; therefore, they fly off in every direction.

Liquids poured into any container will take the same shape. Gases will completely fill any container.

Solids are actually made up of small grains of material. Between the grains are spaces and pores. These spaces and pores may be open or they may be filled with impurities from other materials.

## CHEMICAL TERMS

Atom - An atom is the smallest part of an element.

Element - An element is what our earth and atmosphere is made of, such as oxygen, iron, hydrogen, calcium and sodium. There are about 104 known elements.

Molecule - The smallest particle of a compound. One atom of sodium and one atom of chlorine combine to form a molecule of sodium chloride (table salt).

Compound - The material formed when two or more elements combine chemically. If oxygen combines chemically with iron, a compound, iron oxide or red iron rust as we know it, is formed.

Symbols - Abbreviations that are used for elements, such as H for hydrogen, O for oxygen, C for carbon, etc.

Formula - Two or more symbols put together to show the makeup of a compound, such as $H_2O$ = water, NaCl = salt, and HCl = hydrochloric acid.

Equation - A short method of showing a chemical reaction, such as $\mathrm{Na} + \mathrm{Cl} \longrightarrow \mathrm{NaCl}$ (table salt).

Ion - An atom that has lost or gained electrons, and has become unbalanced electrically. Ions are very active and will form compounds easily.

Cation - A positively charged ion, and shown as a plus, $Na^+$.

Anion - A negatively charged ion, and shown as a minus, $Cl^-$.

Organic - Materials composed of carbon and hydrogen, and are produced by plants and animals. Examples of organic materials are skin, animal hair, leaves, wood and human waste.

Inorganic - Material that is not organic, such as rock, dirt, water and gases.

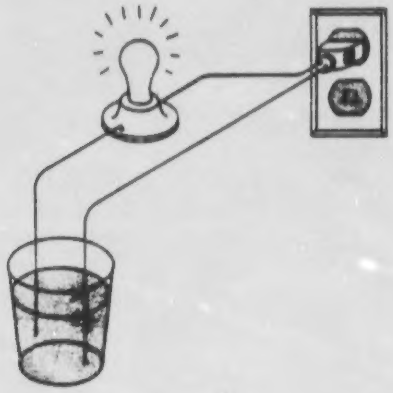
## THEORY OF IONIZATION

We know if we put table salt in a glass of water, it will dissolve. After the salt has dissolved, a very strange thing happens. Let's work up to this strange event slowly.

We already know that table salt is sodium chloride or NaCl. When NaCl is dissolved in water, the Na loses its grip on the Cl, and they actually drift apart. Imagine a lot of little Nas and a lot of little Cls floating around in the glass.

By experimentation, we know the Na has a positive charge, which makes it a cation. The Cl has a negative charge, and this makes it an anion.

Positive ions or cations have the ability to carry an electric current through water. To prove this, we can fill a glass with water, dump in a teaspoon of salt, and rig up an electrical extension cord and light bulb as shown.



When a substance comes apart in water, and has the ability to carry current, it is said to ionize. Many materials, such as acids, bases and salts, will ionize in water. Organic material, normally, does not ionize.

What is ionization? Now, you know.

## ACIDS

What is an acid? An acid is what goes into a car battery. An acid is what digests your food in your stomach. An acid is what makes a bottled soft drink fizz when it is opened. An acid is a substance, usually liquid, that contains hydrogen and ionizes in water.

Acids will eat up iron but not copper. Some acids are very strong and some are quite weak. Strong acids ionize easily; weak acids do not ionize very well.

Strong acids are dangerous and should be handled with care. You can identify a sloppy chemist by counting the acid holes in his clothing.

When an acid is poured into water, the hydrogen in the acid ionizes, or breaks away, and floats around in the water. It is so active that it will combine with almost anything it contacts.

We use acids in some water tests and also to help us in softening hard water.

## BASES

A base is the exact opposite of an acid. An acid released the hydrogen cation in water. A base also dissolves in water and releases a negative ion. This anion is what we call a hydroxyl ion, and its symbol is OH.

We find that lye is the strongest base there is. Its formula is NaOH. When NaOH is dissolved in water, the cation Na and the anion OH break apart causing ionization.

Again, there are strong bases and weak bases, and their strength depends on how much they will ionize in water. Bases are used to perform some laboratory water tests and to renew a water demineralizer.

When an acid and a base are mixed, a violent reaction occurs. This reaction is called neutralization. If we use exactly the same amount of each, they will neutralize each other, and we will wind up with salt and water or salty water.

The equation showing this is:

hydrochloric acid + sodium hydroxide $\longrightarrow$ sodium chloride + water

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

## SALTS

The salt you use on your food is sodium chloride. It dissolves easily and tastes good in small amounts.

There are many kinds of salts. All it takes to make a salt is to combine a metal with a nonmetal. An example is to combine iron with chlorine to form iron chloride. Other salts are calcium sulfate, sodium carbonate, magnesium nitrate, etc.

Most salts either taste bad or they are harmful to the body. Sodium chloride is the salt we use because it is pleasant to the taste, dissolves easily, and has no toxic effects.

## CONCENTRATIONS

A spoonful of sugar dissolved in a swimming pool would be a very weak concentration. A spoonful dissolved in a cup of coffee is a strong concentration.

A concentration is an amount of acid, base or salt dissolved in a known amount of solvent.

Some concentrations are strong and contain a lot of dissolved material. The oceans contain much salt, but they can dissolve more salt. The Great Salt Lake in Utah is almost concentrated with salt. It will not dissolve much more.

Under normal temperature, a solution is considered saturated when it can dissolve no more material. If the saturated solution is placed over a burner and warmed up, then it can dissolve some more material, and we call it supersaturated.

In this course, we use a saturated salt solution to renew one of the water softeners.

## TYPES OF CHEMICAL REACTIONS

A chemical reaction is the change that occurs when two chemicals react with each other. There are four types of chemical reactions.

1. Decomposition is one type of chemical reaction. In this type, a substance is broken down into simpler substances. An example would be in the making of iron. When iron ore is mined, the iron is in an oxidized form ($Fe_2O_3$). Placing the ore in large smelters and heating it drives off the oxygen and leaves pure iron. This is decomposition.

2. Chemical combination is a reaction when two materials combine to form a more complex substance. An example would be iron rust. If an automobile is exposed to the dampness in a sea coast town, the metal body will show signs of rust very quickly. The pure iron in the car will begin to unite or combine with oxygen in the air. This reaction is shown in the following equation:

$$4Fe + 3O_2 \longrightarrow 2Fe_2O_3 \text{ (red iron rust)}$$

3. Chemical displacement is a reaction where an element will exchange places with another element. An example would be the placing of an iron nail in a glass of hydrochloric acid. The acid will eat the nail up and gas bubbles will be given off. The gas is hydrogen. The equation for this reaction is as follows:

$$2Fe + 6HCl \longrightarrow 2FeCl_3 + 3H_2$$

4. Double decomposition is a reaction of two substances that form two new substances. We have already seen an example of this when hydrochloric acid (HCl) was mixed with sodium hydroxide (NaOH). The result was salt and water.

## BALANCING CHEMICAL EQUATIONS

Ordinarily, it is not required for water supply personnel to balance chemical equations while working in the field. However, to fully understand the chemical treatment of water, it is very important to be able to solve chemical reactions by using equations.

To learn to add chlorine to water every three hours is not enough. An understanding of what chlorine does is necessary, and this can be realized through chemistry.

The following equation states that when you add sodium hydroxide to sulfuric acid, there is a chemical reaction and you produce sodium sulfate, which is a salt and water:

| | | | | | | |
|---|---|---|---|---|---|---|
| $H_2SO_4$ | + | $2NaOH$ | $\longrightarrow$ | $Na_2SO_4$ | + | $2H_2O$ |
| Sulfuric Acid | | Sodium Hydroxide | | Sodium Sulfate | | Water |

An equation makes a statement concerning a chemical change.

An Electromotive Force Series Chart (EMF) is an aid to solving equations. An EMF Series Chart is a grouping of the elements according to their electrical potential, with those having the greatest electrical potential located at the top of the chart. Examine the two rules stated in Figure 1. Referring to Figure 1, we find that potassium (K) can displace iron (Fe) from a compound, but iron (Fe) cannot displace potassium (K).

| POSITIVE CHART | NEGATIVE CHART |
|---|---|
| Lithium Li | Fluorine F |
| Potassium K | Chlorine Cl |
| Calcium Ca | Oxygen O |
| Sodium Na | Bromine Br |
| Magnesium Mg | Iodine I |
| Aluminum Al | Sulfur S |
| Manganese Mn | Phosphorous P |
| Zinc Zn | Nitrogen N |
| Chromium Cr | Carbon C |
| Iron Fe | Silicon Si |
| Tin Sn | |
| Lead Pb | |
| Hydrogen H | |
| Copper Cu | |
| Silver Ag | |
| Platinum Pt | |
| Gold Au | |

**RULES**

1. With reference to the above chart, any element which appears above another element will replace the lower element from its compound.
2. With reference to the above EMF Series, any element which appears below another element will not replace the higher element from its compound.

Figure 1. Electromotive Force (EMF) Series Chart

140

Figure 2 is another EMF Series Chart that is a bit broader in scope than Figure 1. Figure 3 is a valence of common ions chart which is merely a chart for reference to determine the valence of any given ion. The valence of an ion determines the proportion present when it combines with another ion. It is the number of positive or negative charges of the ion.

| POSITIVE | HYDROGEN | NEGATIVE |
|---|---|---|
| Cesium | Copper | Fluorine |
| Rubidium | Arsenic | Chlorine |
| Potassium | Bismuth | Oxygen |
| Sodium | Antimony | Bromine |
| Lithium | Mercury | Iodine |
| Calcium | Silver | Sulfur |
| Magnesium | Palladium | Phosphorous |
| Aluminum | Platinum | Nitrogen |
| Manganese | Gold | Carbon |
| Zinc | Osmium | Silicon |
| Chromium | | |
| Cadmium | | |
| Iron | | |
| Cobalt | | |
| Nickel | | |
| Tin | | |
| Lead | | |

Figure 2. EMF Series Chart

| NAME | SYMBOL & CHARGE | NAME | SYMBOL & CHARGE |
|---|---|---|---|
| Acetate | $C_2H_3O_2^-$ | Hydroxide | $OH^-$ |
| Aluminum | $Al^{+++}$ | Hypochlorite | $ClO^-$ |
| Ammonium | $NH_4^+$ | Iodate | $IO_3^-$ |
| Antimony | $Sb^{+++}$ | Iodide | $I^-$ |
| Barium | $Ba^+$ | Lead (plumbous) | $Pb^{++}$ |
| Bicarbonate | $HCO_3^-$ | Magnesium | $Mg^{++}$ |
| Bismuth | $Bi^{+++}$ | Manganous | $Mn^{++}$ |
| Bromide | $Br^-$ | Mercurous | $Hg^+$ |
| Cadmium | $Cd^{++}$ | Mercuric | $Hg^{++}$ |
| Calcium | $Ca^{++}$ | Nickel | $Ni^{++}$ |
| Carbonate | $CO_3^=$ | Nitrate | $NO_3^-$ |
| Chlorate | $ClO_3^-$ | Nitrite | $NO_2^-$ |
| Chloride | $Cl^-$ | Oxalate | $C_2O_4^=$ |
| Chlorite | $ClO_2^-$ | Oxide | $O^=$ |
| Chromate | $CrO_4^=$ | Perchloride | $ClO_4^-$ |
| Chromic | $Cr^{+++}$ | Permanganate | $MnO_4^-$ |
| Cobaltous | $Co^{++}$ | Phosphate (ortho) | $PO_4^{\equiv}$ |
| Cupric | $Cu^{++}$ | Potassium | $K^+$ |
| Cupric Ammonia | $Cu(NH_3)_4^{++}$ | Silicate (ortho) | $SiO_4^{\equiv}$ |
| Cuprous | $Cu^+$ | Silver | $Ag^+$ |
| Cyanide | $Cn^-$ | Sodium | $Na^+$ |
| Dichromate | $Cr_2O_7^=$ | Strontium | $Sr^{++}$ |
| Ferric (iron) | $Fe^{+++}$ | Sulfate | $SO_4^=$ |
| Ferricyanide | $Fe(CN)_6^{\equiv}$ | Sulfide | $S^=$ |
| Ferrous (iron) | $Fe^{++}$ | Thiosulfate | $S_2O_3^=$ |
| Fluoride | $F^-$ | Tin (stannous) | $Sn^{++}$ |
| Formate | $HCO_2^-$ | Zinc | $Zn^{++}$ |

Figure 3. Valence of Common Ions

Consulting Figure 3, we find that calcium has a valence of "two plus." Carbonate has a valence of "two minus." Like charges tend to repel each other while unlike charges tend to attract each other. Calcium carbonate is written chemically as $CaCO_3$. The "two plus" charges of calcium and the "two minus" charges of carbonate are attracted to each other.

Look up the valence of sodium (Na) and hydroxide (OH). You will find that sodium is "one plus" and hydroxide is "one minus." If we write the chemical formula for sodium hydroxide, it is written NaOH. The "one plus" and "one minus" charges of the two ions are attracted to each other. A working rule concerning compounds can be stated. In any compound, the sum of the positive charges is equal to the sum of the negative charges.

Referring again to Figure 3, let us write the chemical formula for sodium carbonate. We find the symbol for sodium to be Na and the valence is "one plus." The symbol for carbonate is $CO_3$ and the valence is "two minus." To satisfy the rule from the preceding paragraph, sodium carbonate could not be written $Na^+CO_3^=$ because the sum of the plus and minus charges are not equal. Correctly written, it would be $Na^+{}_2CO_3^=$. The small "2" indicates that there are two sodium ions present, each having a valence of "one plus." Therefore, we have a total of "two plus" charges and our rule is satisfied.

Anytime a small number is used in a chemical formula, it applies only to the element or radical which precedes it. A large number is used in front of an entire compound and applies to everything within that compound.

Anytime you write a chemical equation, you do not lose or gain a single ion. All have to be represented in the equation. They may be arranged into new or different compounds in the reaction, but the total ions of each particular ion must be equal on both sides of the arrow representing a reaction. Looking at a typical reaction with the valence of each ion printed in, let us examine the reaction:

$$Ca^{++}Cl_2^- \; + \; Mg^{++}SO_4^= \longrightarrow Ca^{++}SO_4^= \; + \; Mg^{++}Cl_2^-$$

The chemical symbol for chloride is Cl and its valence is "one minus." Note in the equation that $Cl^-$ is used twice and each time $Cl^-$ ions are required to balance the compounds.

Note that in each compound, the sum of the plus and minus charges are equal.

Note also that on each side of the arrow, we have the same number of ions we started with, but we have formed two entirely new compounds.

To the left of the arrow, we have one calcium (Ca) and two chlorides ($Cl_2$). We also have one magnesium (Mg) and one sulfate ($SO_4$). To the right of the arrow, we have one calcium (Ca) and one sulfate ($SO_4$). We also have one magnesium (mg) and two chlorides ($Cl_2$). This represents a balanced equation.

There is a methodical step-by-step procedure which, if followed, will result in balanced equations. These are listed in proper sequence.

1. Write down the chemical formulas of the two compounds you are going to react. This may be done by consulting Figures 1 or 3.

2. Consult the EMF Series Chart and determine which cation is the more active. Write the symbol for this cation on the right side of the equation.

3. Combine with this cation the anion of the less active cation.

4. Combine the remaining cation and anion into the equation. The cations are always written first.

5. Check each compound in the equation for valence. The total plus and minus charges of each compound must be equal.

> NOTE: If an ion needs to be increased, use SMALL NUMBERS ONLY. Anytime you increase a radical, inclose it in parentheses to indicate that the increase applies to the entire radical and not just the last atom of that radical.

6. When each compound is balanced, count the ions on both sides of the arrow. They have to be equal on both sides.

> NOTE: If an ion has to be increased here, use LARGE NUMBERS ONLY preceding the compound. Remember also, this will increase everything within that compound.

7. Check the equation and make sure that only the simplest whole numbers have been used. For example: $H_2(OH)_2$, more simply written would be $2H_2O$.

Here is a situation problem, and we will use the 7 rules to balance the equation.

Situation: Represent the addition of sodium hydroxide to sulfuric acid in a balanced equation.

1. Write down the formulas for the reacting compounds from Figures 1 or 3.

$$H_2SO_4 + NaOH \longrightarrow$$

2. Consult the EMF Series Chart and determine the more active cation and put it on the right side of the equation. (In this case, it is Na.)

$$H_2SO_4 + NaOH \longrightarrow Na$$

3. Combine with this cation the anion of the less active cation which, in this case, is hydrogen. (Hydrogen's anion is the $SO_4$ radical.)

$$H_2SO_4 + NaOH \longrightarrow NaSO_4 +$$

4. Combine the remaining cation ($H_2$) with the remaining anion (OH), writing the cation first.

$$H_2SO_4 + NaOH \longrightarrow NaSO_4 + H_2OH$$

5. Check each compound to see that the total plus and minus charges are equal.

$$H_2{}^+SO_4{}^= + Na^+OH^- \longrightarrow Na^+SO_4{}^= + H_2{}^+OH^-$$

First of all, $H_2SO_4$: The hydrogen has a valence of "one plus" and the sulfate radical "two minus," but note the small 2 following the hydrogen which means there are two hydrogen ions, each having "one plus" or a total of two plus charges.

The second compound, sodium hydroxide (NaOH), is balanced with "one plus" and "one minus" charge.

The first compound on the right side of the equation is not balanced. The Na ion has a "one plus" valence while the $SO_4$ ion has a "two minus" valence. To make them equal, we need another plus charge. We can get it by adding another sodium (Na) and have a total of two plus charges and two minus charges. Now our equation looks like this:

$$H_2{}^+SO_4{}^= + Na^+OH^- \longrightarrow Na^+{}_2SO_4{}^= + H^+{}_2OH^-$$

Looking at our final compound, we find that hydrogen has a valence of "one plus" but there is a small "2" there for a total of "two plus" charges. The OH radical has a valence of "one minus." To make the total of the charges agree, we must increase the total minus charges by one. This is accomplished by using a small "2" and we will have "two minus" charges. Our equation now looks like this:

$$H_2^{+}SO_4^{=} \ + \ Na^{+}OH^{-} \longrightarrow Na^{+}{}_2SO_4^{=} \ + \ H^{+}{}_2(OH)^{-}{}_2$$

Remember, when increasing a radical, parentheses must be used to indicate that the increase applies to everything contained in the radical.

6. This rule concerns the equality of ions on both sides of the equation. We must end up with the same number we started with.

Reading the equation from left to right, hydrogen is the first ion we have to count. There are two hydrogen ions in the $H_2SO_4$ compound and one in the NaOH compound for a total of three.

Counting the hydrogens on the other side of the equation, there are none in the $Na_2SO_4$, but there are four in the $H_2(OH)_2$ compound.

To make these equal, we will have to add one hydrogen ion to the left side. Since the $H_2SO_4$ already has two hydrogens, let us add our new one to the NaOH compound. We are through using small numbers now, so our equation looks like this:

$$H_2^{+}SO_4^{=} \ + \ 2Na^{+}OH^{-} \longrightarrow Na^{+}{}_2SO_4^{=} \ + \ H^{+}{}_2(OH)^{-}{}_2$$

Note that the large "2" does not change the valence balance of the compound because the large numbers apply to everything within the compound.

The next ion to be counted is the S ion in the sulfate radical. There is one on the left and one on the right, so it is balanced.

The next ion to be accounted for is oxygen. The small "4" in the compound $H_2SO_4$ indicates that there are 4 oxygen ions present. In the compound 2NaOH, there are two oxygen ions present. The large "2" preceding the compound applies to everything within the compound. Four and two gives a total of six on the left.

On the right, there are four oxygen ions in the compound $Na_2SO_4$ and two more in the compound $H_2(OH)_2$. Four and two are six, so the oxygen ions are equal.

The next ion is sodium in the compound 2NaOH. There are two Na ions on the left and two on the right, so they are equal.

The two remaining ions in the 2NaOH compound, O and H, have already been counted, so the equation is balanced.

7. We have one more rule to satisfy however; are the simplest whole numbers used? Look at the compound $H_2(OH)_2$. There are a total of four hydrogen ions and two oxygen ions present, with a hydrogen ion on each end of the compound. Hydrogen being a cation should be written first. $H_2(OH)_2$ could be more simply written as $2H_2O$. The final equation would look like this:

$$H_2^{+}SO_4^{=} + 2Na^{+}OH^{-} \longrightarrow Na^{+}_{2}SO_4^{=} + 2H^{+}_{2}O^{=}$$

Balancing equations consists of making all totals equal following seven steps or rules in chronological order. Practice in applying these rules will enable you to solve all water treatment reactions.

## EXPRESSION OF TEST RESULTS

Water tests are meaningless unless they are expressed in some unit of measurement. Those listed below are the ones most commonly used in our field.

### Parts Per Million (PPM)

A part per million is always expressed as a weight-to-weight ratio. An example is one pound of chlorine to one million pounds of water.

### Grains Per Gallon (GPG)

The grain is the smallest unit in the English system of measurements pertaining to mass (weight). One pound equals 7,000 grains. If you wish to convert to PPM, use the factor: 17.1 PPM equals 1 GPG, U.S. Gallon.

### Liter

The liter is just a bit larger than a quart. It contains 1,000 milliliters. There are 3.8 liters in a gallon.

### Gram

A gram is the weight of 1 milliliter of water.

### Milligrams Per Liter (Mg/L)

Another method of expressing one part per million (PPM).

## SUMMARY

Matter includes everything that occupies space and has weight. Matter includes all solids, liquids and gases.

Understanding of commonly used chemistry terms is essential to the understanding of water treatment.

Ionization is a characteristic of chemicals that cause them to react in various reactions. By showing the reactions in an equation, an exercise in balancing can show the desired results.

Performing water tests are meaningless unless the results are expressed in some measurement.

## QUESTIONS

1. Why is a shadow not considered matter?

2. What is the smallest part of an element?

3. When two elements combine chemically, what is the name of the resultant material?

4. In the hydroxide radical OH, the O is which element?

5. Write the formula for water.

6. What allows two different ions to combine?

7. What one element is common to all acids?

8. If you needed a very strong base, which compound would be best to use?

9. If a warm supersaturated solution is cooled, what is likely to happen?

10. Write the equation of sodium hydroxide plus calcium chloride.

11. Balance the above equation.

12. What is meant by a part per million?

## REFERENCES

Standard Methods
AFM 85-13, Maintenance and Operation of Water Plants and Systems
AFM 85-14, Maintenance and Operation of Sewage and Industrial Waste Plants and Systems

## AIR FORCE WATER REQUIREMENTS

### OBJECTIVE

The purpose of this study guide is to aid you in becoming familiar with the water requirements of an Air Force Base.

### INTRODUCTION

Every Air Force base has a need for a good water supply. The uses and conservation of water will be given under the following subjects:

- DOMESTIC USES
- INDUSTRIAL USES
- QUANTITY NEEDED
- QUALITY NEEDED
- CONSERVATION

### DOMESTIC USES

The word domestic means home. The use of water around a home would include drinking, cooking, laundry, bathing, flushing the toilet and even watering the trees and grass.

Some homes have private swimming pools so this water is also considered as domestic.

The Air Force uses domestic water just as you did at home.

Water used to fight fires also comes from the domestic supply. When large barracks or warehouse catches on fire the fire department needs a supply of water that won't run out. The domestic water stored in the water towers will give the pressure needed and the amount to put out large fires.

## INDUSTRIAL USES

Do you remember seeing water trickling down a large cooling tower. This is industrial water. There are two common uses of industrial water on an Air Force installation. Water to furnish Air Force operating equipment and heated water for sanitation purposes.

Hospitals need pure water for mixing medicines, so they use distilled water. Airplanes use pure water to squirt in the engines. This makes them go faster. The water they use goes through a demineralizer. This removes minerals from the water.

Boilers that heat large amounts of water for laundries use specially treated water to prevent a white scale from covering the insides of the boilers.

Almost all machinery that uses water can be ruined by using the same water that you drink. Treating water, so it can be used, is part of your job. You will be taught many ways to treat water so it will do the job that is needed.

## QUANTITY NEEDED

The amount of water needed by an Air Base will depend on several factors. If a base has a large Wherry or Capehart housing, the quantity of domestic water needed will be larger.

The effective population which is all the residents living in the dormitories or in government housing, must be furnished domestic water.

At the beginning of each workday the civilians that work on the base start arriving. These nonresidents help make up the authorized population of the base. Water must be furnished so each may do his job properly.

Some bases have large hospitals. Hospitals use large amounts of water. Bathing of patients, mopping floors, kitchen uses and hospital laundries are some of the uses.

The amount of water used by a base will vary both day and night and summer and winter. If a large fire occurs and the fire trucks have to pump water all night then the base could run low on water supply. This would be called an unusual peak demand.

Fire fighting has to be taken into account when the base is first built so enough water will be on hand if needed. If the base grows,then more water towers are needed.

## QUALITY NEEDED

There are two types of water consumed on a military base which includes domestic and industrial.

### Domestic Water

Every base must have water that is clear, have an acceptable taste and be free of bacteria. When water meets these requirements it is called POTABLE water.

Even though water is potable there are somethings that make it undesirable for domestic uses. These are odors and hardness. Odors come from sour gases in the water of from minerals such as sulphur.

Some waters form a white scale in water glasses, pipes, and on anything where the water can evaporate. This white scale is the result of hard water. When water contains to much hardness the water must be softened. You will learn how to do this in a later lesson.

### Industrial Water

Even if water is clear, has no taste or odor and has no germs it may need more treatment before it can be used in machinery.

Since industrial water is used in boilers, heating systems, photo labs, chemistry labs, hospital labs, and aircraft it has to be completely free of minerals. This even includes dissolved gases such as oxygen and carbon dioxide.

Corrosive agents, scale forming minerals and dirt must be removed otherwise the equipment of industry would soon rust out or stop up.

Control of water quality is the responsibility of the base commander but he delegates this authority to the civil engineering officer for providing a safe and satisfactory water supply.

To the base medical officer goes the responsibility of approving the purity of the water and recommending any remedial action if needed.

## CONSERVATION

Water is more important to human existence than gold. The world is rapidly using up all available water sources.

We shouldpractice water conservation because it saves money, prevents water shortages, lessens the sewage plant load and most of all saves one of our greatest natural resources.

Water waste can be recognized by constantly flowing urinals, fountains and wash basins.

Excessive lawn watering, water running down the curbs, and leaking water faucets is wasted water.

Some water systems can build pressures over 60 psi in the distribution lines. This type system can waste water as the amount of water coming out is more than is necessary for normal usage, also more leaks will develop.

How can you prevent water waste? You can practice water conservation programs, inform the public of conservation measures and then use a follow-up inspection to insure effectiveness of the program.

## SUMMARY

Domestic water is the water that is used for personal needs such as drinking, bathing, and cooking.

Industrial water is the specially treated water that is used in heavy equipment, hospitals and aircraft.

The quantity of water needed by an Air Force Base will vary from time to time but at all times must be able to meet peak demands.

The quality of the water needed will vary as to its use. Potable water will satisfy most base housing but is not pure enough for other uses.

Conservation of water is a job for everyone. You can help do your part by following a simple water saving program.

## QUESTIONS

1. Name four uses of domestic water.
2. How do you use water any differently than you did at home?
3. What is industrial water?
4. What is the effective population of an Air Base?
5. What is the authorized population of an Air Base?
6. What is potable water?
7. Name two substances that can give water an odor.
8. Why does industrial water have to be treated for impurities even if it is good to drink?
9. Name three practices that indicate water is being wasted.
10. Why should we urge everybody to conserve the use of water?

## REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. AFM 88-10, Water Supply

## TYPES AND CHARACTERISTICS OF WATER SOURCES

### OBJECTIVE

The purpose of this study guide is to aid you in learning the effects and characteristics of impurities in supply water and the various water classifications.

### INTRODUCTION

Absolutely pure water is never found in nature. For military use, water must be free of disease producing organisms, poisons and excessive amounts of minerals or organic matter. Under these conditions, the water is safe for drinking, cooking and washing. When time and equipment permit, the water should be clear, cool and free of objectionable tastes and odors. Every effort should be made to provide water of excellent quality because of the effect it has on the health and morale of the men.

An adequate supply of water is essential to the success of any operation. Man cannot live without water; it is more essential to him than food. Water must be rendered safe for human consumption by treatment to eliminate disease germs and injurious chemicals.

This study guide should acquaint you with water sources and various types of impurities associated with them. This will be covered under the following main topics:

- HYDROLOGIC CYCLE
- CONTAMINATED, POLLUTED, PALATABLE AND POTABLE WATER
- CLASSIFICATION OF NATURALLY OCCURRING WATER SUPPLIES
- IMPURITIES IN WATER
- PHYSICAL AND CHEMICAL PROPERTIES
- HARDNESS AND OTHER CHARACTERISTICS DUE TO DISSOLVED MINERALS
- DISSOLVED GASES

This study guide will not cover all the information you need to know and study of additional material is recommended.

### HYDROLOGIC CYCLE

The hydrologic cycle is the term used to describe the natural circulation of the water in, on and above the earth. Water occurs in many forms as it moves through this cycle. Figure 1 is a simplified illustration showing the more important procedures in the cycle.

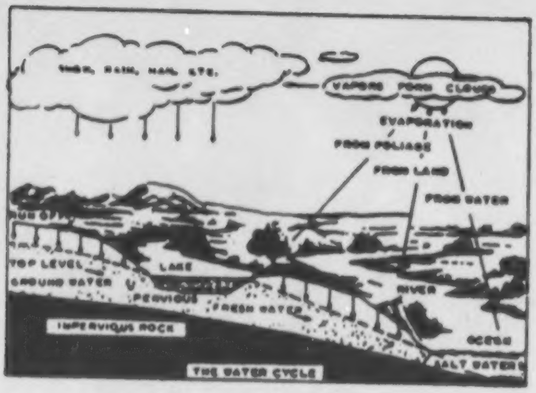


Figure 1. Hydrologic Cycle

The procedures in the hydrologic cycle include evaporation, precipitation, transpiration, infiltration, and run-off. Water is evaporated from the water surfaces, land surfaces, and by transpiration from plants. It is then condensed to produce cloud formations and returns to earth as rain, snow, sleet or hail. A portion of the precipitation evaporates, and flows over the earth as run-off into lakes and streams, and the remainder goes into the soil and thence into underlying rock formations by seepage or infiltration. Eventually the water which has seeped through the earth will find its way to the surface through springs or will flow through porous median until intercepted by streams, lakes or the ocean.

The cycle does not always progress through a regular sequence; steps may be omitted or repeated at any point. For example, precipitation in hot climates may be almost wholly evaporated and returned to the atmosphere. In such an instance the steps of infiltration, transpiration, and run-off are omitted.

## CONTAMINATED, POLLUTED, PALATABLE AND POTABLE WATER

Contaminated water contains potentially disease producing organisms or poisonous substances which make it hazardous and therefore unfit for human consumption or domestic use. Water may be contaminated but not necessarily polluted.

Polluted water is water containing substances such as garbage, industrial waste or mud, which makes it objectionable because of appearance, taste or odor. Polluted water is usually contaminated and may be easily detected.

Palatability of water is the term used which describes the characteristic of being pleasing to the sense of taste. To be palatable, water should be significantly free from color, turbidity, taste, odor and should be cool and aerated. At least four human perceptions can be used in judging these qualities. They are the senses of sight (color and turbidity), taste, smell (odor), and touch (temperature). However, it must be understood that palatable water is not always safe to drink.

Potable water is water that is free from disease-producing organisms, organic and inorganic poisonous substances and is safe for human consumption. Although potable water is safe to drink it may not be palatable.

## CLASSIFICATION OF NATURALLY OCCURRING WATER SUPPLIES

### Surface Water

For convenience, naturally occurring surface water supplies may be divided into three primary categories: fresh water, brackish water, and salt or sea water.

Fresh Water. Fresh water includes flowing streams or rivers and water impounded by lakes or reservoirs. Most of the surface waters in the United States are fresh water. Air Force standards permit maximum chlorides of 250 ppm (parts per million), maximum sulfates of 250 ppm, and a maximum total dissolved solids of 500 ppm.

Brackish Water. Brackish water is found in many regions throughout the world, but occurs most frequently as ground water in arid or semiarid climates. Brackish waters are highly mineralized and contain dissolved solids in excess of 500 ppm, which make them objectionable as drinking water supplies. Total dissolved solids may be as high as 15,000 ppm. Both alkalinity and salinity range from very high to very low.

Salt or Sea Water. Salt or sea water contains total dissolved solids above 15,000 ppm. This is an approximation, since no clear-cut line of distinction can be drawn between brackish and salt water. Typical salt water has a very high sodium chloride content and a low alkalinity. It is generally found only in a free body of water such as ocean, sea or estuary. The most abundant source, the oceans, may contain total dissolved solids up to 35,000 ppm. Inland seas such as the great Salt Lake may have total dissolved solids of 200,000 ppm.

### Ground Water

Ground water is made up of all water found beneath the surface of the earth. To tap this source of water requires digging a well as the farmers did, or drilling a hole in the ground. Water cannot be found every time a well is drilled so several attempts may be necessary. Water may be found from 10 feet to several hundred feet deep. The depth at which water is found is called the water table. During dry years the water table can drop several feet and the wells may have to be dug deeper.

## IMPURITIES IN WATER

As water goes through its hydrologic cycle, it gathers a lot of impurities. Dust, smoke and gases fill the air and tend to contaminate rain and snow. As runoff, water picks up silt, chemicals, and disease organisms. As it enters the earth through seepage and infiltration, some of the suspended impurities may be filtered out, but at the same time, other minerals and chemicals are dissolved and carried along. It is now ground water in an underground deposit and although it may now become less contaminated or polluted, it is not necessarily pure and may contain disease organisms as well as harmful chemicals.

In addition to the impurities in water resulting from infiltration, many may be contributed by the carelessness of man. Examples of impurities created by man are garbage, sewage, industrial waste, insect sprays and the use of chemical, biological or radiological agents.

Impurities in water are either suspended or dissolved. The suspended impurities are usually more dangerous to health. They include mineral matter, disease organisms, silt, bacteria and algae, and must be destroyed or removed from water that is to be consumed by troops.

## PHYSICAL AND CHEMICAL PROPERTIES

Water takes on various characteristics and properties as it passes over and through the earth. These characteristics and properties vary and are dependent on the materials encountered. They may be classified according to means of detection as physical (detected by one or more of the five senses) and chemical (detected by chemical analysis). The most important physical characteristics are turbidity, color, odor, taste, and temperature. The most important chemical characteristics are acidity, alkalinity, hardness and corrosiveness. Sometimes these two types of characteristics overlap; for example, iron in water is a dissolved mineral detectable by chemical analysis, yet its color and taste are also physical.

### Turbidity

Turbidity is a muddy or unclear condition of water, caused by particles of sand, silt, clay or organic matter being held in suspension. The faster water flows, the more material it picks up and the larger the size of the pieces carried along. As water slows down, the larger particles settle out. When the flow stops, all but the finest particles settle out. Clay and silt remain suspended in water longest, because their particles are smallest.

The removal of turbidity is essential in the production of potable water. Such removal reduces contamination, extends the time between backwashing of filters, decreases chlorine demand, improves disinfection and improves the acceptability of the finished water. The Air Force Medical Service requires turbidity removal because suspended particles often contain disease-producing organisms.

### Color

Color in water is due to the presence of colored substances in solution, such as vegetable matter dissolved from roots and leaves, human and iron salts. True color is that due to substances in true solution; apparent color includes true color and also that due to substances in suspension. Water taken from swamps, weedy lakes and streams containing vegetation is most likely to be colored. Color may also be caused by industrial wastes, iron and manganese salts, and turbidity. Turbidity is apparent color, rather than true color caused by materials of vegetable origin. Color as such is harmless, but objectionable due to its appearance and to the tastes and odors sometimes associated with it.

### Odors and Taste

Taste and odors found in water are caused by algae (small water plants), decomposing organic matter, dissolved gases, or industrial waste. Mineral substances may also be a cause. The chlorination of water may produce odors and tastes of its own or increase those of the responsible organisms through destruction. Potability is not normally affected by the presence of odors and tastes. On the other hand, palatability is frequently affected, particularly when an agent such as bone or fish oil is present. Water containing one of these agents in noticeable quantities is unpalatable.

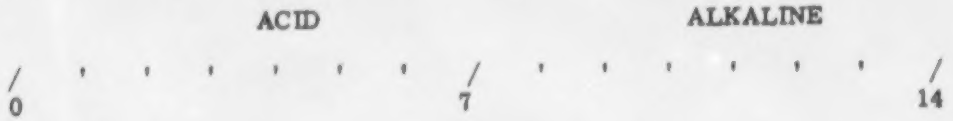
### Temperature

Warm water tastes flat. Lowering the temperature of water suppresses odors and tastes, therefore, increases its palatability. In the summer the temperature of deep lakes and reservoirs decreases sharply from top to bottom. By lowering the depth of intake, it may be possible to draw relatively cool water even during hot weather. Water should be drawn from the lower depths when possible. Cool water is more viscous than warm water and thus is more difficult to filter and coagulate. Water treatment rates should be reduced when water temperatures are less than 45°F.

### Acidity and Alkalinity

Some impurities found in water cause it to be either acid or alkaline in its chemical composition. Since acidity and alkalinity play an important role in water treatment, the degree of alkalinity or acidity and their relationship in a given water source must be determined.

The pH value of a water sample is a measure of the acidity or alkalinity of the water. The pH value ranges from 0 - 14, with 7 the neutral point. A pH value ranging from 7.0 down to 0 indicates decreasing alkalinity. A color comparator or an electric pH meter can be used to determine the pH of a sample.



## HARDNESS AND OTHER CHARACTERISTICS DUE TO DISSOLVED MINERALS

### Hardness

The total amount of solids in water depends upon the material with which it has been in contact, the length of exposure and the amount of carbonic acid present. Hardness results from the presence of soluble salts of alkaline earths. The most common alkaline earths are calcium and magnesium. Hardness is undesirable in that it consumes soap, makes water less satisfactory for cooking and produces scale in boilers and distillation units. The following minerals cause hardness in water.

1. Calcium Carbonate is alkaline and only slightly soluble; causes carbonate hardness and alkalinity in water.

2. Calcium Bicarbonate contributes to the alkalinity and carbonate hardness of water. Calcium bicarbonate, when heated, produces carbon dioxide and calcium carbonate. This calcium carbonate precipitates as scale in boilers and distillation units.

3. Calcium Sulfate or Gypsum. Causes noncarbonate hardness in water. Being more soluble in cold water than in hot, it separates from the water in boilers and forms scale on boiler tubes.

4. Calcium Chloride causes noncarbonate hardness in water.

5. Magnesium Carbonate (Magnesite) and magnesium bicarbonate act the same in water as calcium carbonate and bicarbonate.

6. Magnesium Sulfate (Epsom Salts) adds to the noncarbonate hardness of water and causes boiler scale. In amounts greater than 500 parts per million in drinking water, it acts as a laxative.

7. Magnesium Chloride has the same properties and effects as calcium chloride. However, the scales formed are somewhat softer than those formed by calcium chloride.

### Iron

Iron is undesirable because it imparts a rusty color and objectionable taste to water. It also forms crusts in plumbing and piping. When iron is present in water, bacteria may also be present. These organisms cause taste and odor as well as clogging of pipes.

### Manganese

While not encountered as often as iron, it is found in both surface and ground water. Its presence in water normally causes a grey or black color. Methods of removal are the same as for iron. The total concentrations of iron and manganese in potable water should not exceed 0.3 milligrams per liter.

### Sodium Carbonate (Soda Ash) and Sodium Bicarbonate (Baking Soda)

These increase the alkalinity of the water, thus raising the pH of the water. In steam boilers, hot water heaters and distillation units, these minerals break down and release carbon dioxide, which corrodes metal tubes.

### Sodium Chloride (Table Salt)

Sodium chloride is of importance principally in connection with the salty tastes produced and in identifying the nature of noncarbonate hardness. If present in water in amounts greater than 400 PPM, the taste becomes noticeable.

### Sodium Sulfate (Gluber Salts)

This has a laxative effect when present in drinking water in amounts over 500 PPM. In large amounts, it causes foaming in boilers and distillation units.

## DISSOLVED GASES

The concentration of a gas in water is directly proportional to the concentration, or partial pressure, of the gas in the atmosphere in contact with the water surface. In general, this involves the water temperature, its salinity and the altitude. The gases of primary interest to water supply are:

### Oxygen

Large amounts of dissolved oxygen are found in rain water. The amounts in surface water vary greatly, depending on the amount and type of pollution, the degree of self-purification, the action of algae and the temperature of the water. Polluted water will exhaust the oxygen supply, while clean water will contain a lot of dissolved oxygen. Cold water contains larger amounts of dissolved oxygen than warm; as water temperature rises, the dissolved oxygen is released to the atmosphere. Decreased pressure on water has the same effect, releasing oxygen to the atmosphere. Dissolved oxygen in water and in contact with metals will cause many metals to corrode.

### Carbon Dioxide

The presence of carbon dioxide in water contributes to the degree of hardness and acidity of the water. Water acquires this gas in four ways: from the air by natural movements of water in contact with the air, such as currents and wave action: by contact with decomposing vegetation, which gives off carbon dioxide freely; by the reaction of alum and soda ash in the coagulation process; and by contact with the gas in underground deposits. A high carbon dioxide content usually makes water more corrosive to metals.

### Hydrogen Sulfide

Hydrogen sulfide in solution lends a disagreeable taste and rotten-egg odor to water. Ground water absorbs sulfides by passing over sulfur-bearing rocks. Hydrogen sulfide is also responsible for the destruction of cement and concrete as well as the corrosion of metals. In small amounts, it is unpleasant but not dangerous. In large amounts it is harmful.

## SUMMARY

The hydrologic cycle is the natural circulation of water in, on and above the earth. In the various stages of the hydrologic cycle, the water is in various conditions such as contaminated, polluted, palatable and potable. Water is either obtained from the surface of the earth or deep in the ground. There may be many things in the water such as turbidity, color, odors, bacterias, chemicals, and dissolved gasses.

## QUESTIONS

1. What source of water has the most impurities?
2. What governs the impurities in surface water?
3. What does a high carbon dioxide content do to water?
4. What is turbidity?
5. What is the most common cause of color in water?
6. What causes tastes and odors in water?
7. What is meant by pH value?
8. How is pH value measured"
9. What are the effects of iron and manganese in water?

10. What causes some water to have a "rotten-egg" odor?

REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. TM 5-700, Field Water Supply

# LABORATORY SAFETY

## OBJECTIVES

The objectives of this study guide are to aid you in learning the precautions to take when working with chemicals and laboratory equipment and to aid you in developing general knowledge of first aid requirements in case of an accident while working in the laboratory.

## INTRODUCTION

The work of a laboratory technician in water treatment can be safe if he will use a few simple precautions in the handling and mixing of chemicals, handling glassware, and operating the equipment. Accidents just do not happen; they are caused by unsafe acts or conditions. The skilled operator knows his chemicals, the proper method of mixing them, the correct manner of operating his equipment, and the importance of keeping his mind on his work. The last is very important because many times after an accident, the victim has remarked, "I was not thinking." Information of importance to you in gaining an understanding of how accidents are caused and prevented is presented in this study guide. However, not all the information you need to know is contained here; therefore, additional study on the subject is recommended.

## HANDLING ACIDS AND ALKALIES

Acids and alkalies can cause severe burns when they come in contact with the skin. When handling chemicals, never put your hands to your eyes or face without first washing them. The skin tissue of your face is more sensitive than that of your hands and is more easily irritated. Rubber gloves must be worn when handling concentrated acids to protect your hands. To protect your clothes a rubber apron is worn. Before using these protective devices, they should be inspected to assure they will afford the protection for which they were intended.

When mixing acids with water, the acid should be slowly poured into the water and the solution should be constantly stirred with a glass stirring rod to prevent a concentration of the acid in a small area of the water. Failure to follow this procedure may result in the acid boiling and splattering the surrounding area, causing severe burns to the operators. Never pour water into the acid. Should one of your coworkers get a spray of acid in his face or eyes, do not let him put his hand to his face, place him immediately under a shower where plenty of water can wash away the acid, and then take him immediately to the doctor for further treatment. An accident report should be made as soon as the patient's condition permits.

## CUTS FROM GLASSWARE

Before using any glassware for testing water, an inspection of the article should be made for cracks and rough edges. The rough edges can develop into cracks and when a stopper is applied may break the tube and spill its contents.

When heating a liquid in a beaker or flask, always apply the heat gradually. A large amount of heat concentrated in a small area can set up a strain that might cause the beaker or flask to crack.

## LABORATORY SAFETY EQUIPMENT

Although some differences will be found in safety equipment which has been provided for use in the water testing laboratories, most laboratories will have similar items of safety equipment.

Rubber aprons are provided and should always be worn when you are performing water tests. This practice will protect your clothes from water spills and also from acid and other chemical spills.

Rubber gloves are available and are a "must" when you handle concentrated acids such as sulfuric or nitric acid; also, when handling concentrated caustic solutions such as sodium hydroxide. Most of the acid solutions used in testing water samples are quite weak (N/50) and do not require the use of rubber gloves.

Asbestos gloves are provided for the handling of beakers and other vessels containing hot liquids and also when removing hot samples from a muffle furnace.

Several types of tongs may be provided for handling equipment which cannot be picked up with your bare hands. Some of the tongs have rubber covered tips so that glassware may be handled without danger of cracking. Other tongs are asbestos lined for handling the larger beakers containing hot liquids.

Plastic face shields and eye goggles are provided for your protection when handling concentrated acid or caustic solutions and when heating solutions and evaporating them to dryness over Bunsen burners as there is some danger of spatter just before dryness is reached.

Some laboratories are equipped with emergency showers and also special eye washers. Although this equipment may never be needed, you should give them an operational check at regular intervals, and you should make sure that you know exactly where they are located.

Properly equipped laboratories will be well ventilated and some are provided with exhaust fans for the quick removal of toxic or noxious fumes.

Walkways in the laboratory may be covered with rubber floor mats to lessen the chance of slipping and falling. They also act as an electrical insulator and decrease the possibility of receiving an electrical shock when operating electrical powered stirring machines, etc.

## SUMMARY

Do not forget that most accidents can be prevented. Your part in safety programs is to become familiar with the causes of accidents and to follow the prescribed rules and precautions to prevent them. Some of the conditions which cause accidents are poor housekeeping, horseplay, improper use of equipment and nonobservance of warning signs. Pay attention to the safety procedures in working with laboratory equipment, and the accidents should be few, if any, in this course.

## QUESTIONS

1. What type of injury may result from bodily contact with acids and alkali?

2. What chemical is a safe antidote for acid burns?

3. List five items of safety equipment which should be available in the water testing laboratory.

4. When should personnel performing water tests don a rubber apron?

# COLLECTING AND LABELING WATER AND WASTE SAMPLES

## OBJECTIVES

Upon completion of this unit of instruction, you should be able to collect water samples which are suitable for test purposes from the water treatment plant, designated points in the water distribution system, swimming pool, heating plant, and waste samples from the waste processing plant.

## INTRODUCTION

The collection of water samples and the care given the samples before they reach the water testing laboratory are very important. The biggest problem in the collection of water samples is to collect samples which are truly representative of the water from which they are taken.

Frequent chemical analyses of both raw and treated water are commonly made to plan and control treatment and to insure that the water is satisfactory for industrial purposes, or that it is safe and potable.

Water and waste processing specialists are responsible for the collection of water samples from many sources and may also be responsible for the collection of samples from the waste processing plant on the base.

The information on the collection and care of water samples will be included under the following main topics:

- PURPOSE OF WATER SAMPLING
- PROCEDURES USED IN COLLECTING WATER SAMPLES
- LABELING WATER SAMPLES
- PURPOSE OF WASTE SAMPLING
- PROCEDURES USED IN COLLECTING WASTE SAMPLES

## INFORMATION

### PURPOSE OF WATER SAMPLING

The collection of water samples is a preliminary step to water testing. The purpose of water sampling is to obtain representative samples of water in order that water tests may be performed. The water tests may be required for a variety of reasons, among them being to determine: the suitability of untreated water for a specific use, the water treatment necessary to make the water suitable for use, whether or not the water treatment being given is producing satisfactory results, and the concentration of residual chemicals after treatment.

# PROCEDURES USED IN COLLECTING WATER SAMPLES

## Collecting Samples of Treated Water

Water samples from a water treatment plant are required for both chemical tests and bacteriological analysis. Be sure to use clean sample containers in all cases.

CHEMICAL ANALYSIS. The following instructions should be observed when collecting samples for chemical analysis:

1. Plant - Take sample inside a treatment plant from channels, pipe taps, or other points where good mixing is obtained.

2. Tap or Distribution System - Let water run from tap long enough to draw water from main before taking sample.

3. Sample for dissolved gas test - Take care to prevent change in dissolved gas content during sampling. Flush line, then attach rubber hose to tap, and let water flow until all air is removed from hose. Drop end of hose to bottom of chemically-clean sample bottle and fill gently, withdrawing hose as water rises. Test for the dissolved gas immediately.

BACTERIOLOGICAL ANALYSIS. In obtaining samples for bacteriological analysis, contamination of the sample bottle, stopper, or the sample itself may cause a potable water supply to be reported as nonpotable. Full compliance with the following precautions is necessary to assure the correct analysis.

1. Bottles - Use only clear, sterilized bottles with glass stoppers. Cover stopper and neck of bottle with a square of wrapping paper or other suitable material to protect against dust and handling. Before sterilizing sample bottle to test chlorinated water, place 0.02 to 0.05 grams of sodium thiosulphate, powdered or in solution, in bottle to react with the chlorine residual in the sample. Keep sterilization temperature under 200°C to prevent decomposition of the sodium thiosulphate. Empty bottle, but do not rinse.

2. Sampling from a Tap. After testing for chlorine residual, close the tap and heat the outlet with an alcohol or gasoline torch to destroy any contaminating material that may be in the tip of the faucet. Occasional samples may be collected without cleaning the faucet in order to determine whether certain faucet outlets are contaminated. Flush tap long enough to draw water from main. Never use rubber hose or other temporary attachments when drawing water from the tap. Without removing protective cover, remove bottle stopper and hold it. DO NOT touch the bottle mouth or sides of the stopper. Fill the bottle three-fourths full. Do not rinse the bottle as the sodium thiosulphate will be lost. Replace the cap and fasten the protective cover with the same care.

3. Sampling from Tanks, Pools, Lakes, and Streams. When collecting samples from standing water, remove the stopper as above and plunge bottle mouth down, at least three inches beneath the surface. Fill the bottle, moving it away from the hands so that the water which has contacted the hands does not enter the bottle. Discard a quarter of the water and replace the stopper. For collecting samples from swimming pools, collect the sample from the side of

the pool near the deepest part. Take the sample while the pool is in use, preferably during the heaviest bathing load. Use the bottle containing sodium thiosulphate. For collecting samples from lakes or ponds, the samples can be taken from a boat or pier about 25 feet from shore and in water at least 4 feet deep. Do not collect samples at shore. Collect stream samples from a point where water is flowing, not from stagnant pools. In a meandering stream, collect a sample at a point where flow velocity is normal.

4. Transporting and Storing Samples. Biological changes occur rapidly; therefore, if a test is to be made at the installation, perform the test within one hour if possible, or refrigerate it and test within 48 hours. If the sample is to be tested at a laboratory away from the installation, provide the fastest possible transportation which is practical.

5. Sample Data. Identify each sample fully. Note the sampling point, including the building number for sample of distribution systems, source of water, such as installation water supply, lister bag, raw water, unchlorinated well water, cistern or swimming pool, date of collection, and chlorine residual at the time of collection.

## Collecting Samples of Raw Water (Ground)

The procedure for collecting a raw water sample from a well that is equipped with a pressure pump is as follows:

1. The point of sampling should always be as close to the source as possible.

2. The most desirable points of collection are either from the pump housing itself or from the discharge line as close to the pump as possible. A small rubber hose connected to a short piece of copper tubing and a valve is very satisfactory for a sampling line.

3. It is necessary to flush out the sampling line before the sample is taken.

4. The sampling line should be adjusted to reach the bottom of the sample container.

5. The sample is then permitted to overflow the container to minimize the effects of exposure to the atmosphere.

6. The sample should never be taken in a shallow container such as a pan or a bucket.

7. The container should be capped or corked immediately after the sample is drawn to avoid contamination.

8. Use only clean containers to collect water samples. It is a good practice to always rinse container with some of the sample water before taking sample.

Collecting Samples of Raw Water (Surface)

Surface water usually means water from a lake, stream, or spring. It is difficult to say exactly where the point of sampling should be, because of the varied conditions of surface water. Your judgment and good reasoning is required to select the sampling point where the water is most representative.

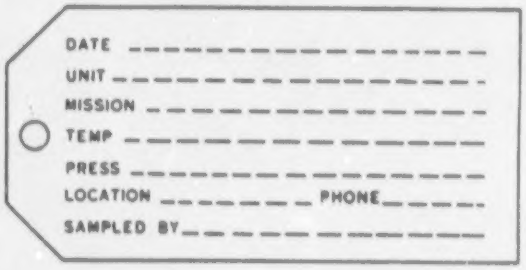
A sample from a lake or stream should never be taken at or near the inlet, a stagnant pool, along the shore, or near the surface, as these waters are neither representative nor pure.

To obtain a sample from a lake, stream, or spring, the container should be thoroughly rinsed, submerged, and uncorked beneath the surface. When the container is full, it should be corked and withdrawn.

## LABELING WATER SAMPLES

Water samples are of little or no value unless they are properly identified. Many times samples lose their identity while being transported from the point of collection to the water testing laboratory. If the containers are properly labeled, there will be little chance of a mix-up. Properly labeled water samples also aid the analyst in filling out his reports as he tests the water.

The label used on the sample container is usually locally designed. Sometimes tags are attached to the container by masking tape or rubber bands. Gummed labels or tags, such as the one shown in figure 1, have proven quite satisfactory. The information required to be written on the label varies, but usually includes, date, unit, specific mission, temperature, pressure in psi, location, phone, and name of person who collected the sample.



DATE ________________

UNIT ________________

MISSION ______________

TEMP ________________

PRESS _______________

LOCATION _______ PHONE _____

SAMPLED BY ____________

Figure 1. Sample Tag

## PURPOSE OF WASTE SAMPLING

The purpose of waste sampling is to obtain a representative portinn of the total wastewater flow so that tests may be made to determine the composition and characteristics of the flow. Samples must also be obtained to determine the effectiveness of treatment and to establish whether or not there is a need for a change in treatment or procedure.

Types of Samples

Sewage is composed of 99.9 percent water and 0.1 percent solids. This 0.1 percent consists of both organic and inorganic matter which may be dissolved, or in a suspended condition with varying characteristics. The solids tests that are run will give you a good idea of how the sewage should be treated. Before the tests can be run you must collect representative samples of the flow. Waste samples are grouped into two general classes, depending upon the manner in which the samples were taken. The two classes are grab samples and composite samples.

GRAB SAMPLES. Grab samples are those taken by sampling the sewage at one point, at one time. They cannot give much information about the average conditions of the sewage throughout the day, but they do show a condition needing immediate control. Some tests require grab samples since there are rapid changes of some substances in a given length of time. The settleable solids test is always made from a grab sample.

COMPOSITE SAMPLES. Composite samples consist of individual samples taken at regular intervals over a selected period of time and thoroughly mixed prior to testing. The composite sample may be mixed after the addition of each individual sample, or at the end of the sampling period. Raw sewage samples are collected hourly unless special studies or tests are being made. The volume of individual samples taken should be in proportion to the volume of sewage flow at the time the sample is taken. Thus a high flow will have a larger sample than a low flow. The samples may be kept in wide mouthed, stoppered glass bottles, or covered enamel pails, and must be kept refrigerated until they are tested. This helps to slow down the rate of decomposition of the sewage. Composite samples are taken for suspended solids test, total solids test, and volatile solids test. The usual sampling period is 24 hours, although shorter periods may be used.

Obviously the advantage of composite samples is that this gives a better idea of average conditions. This is necessary when planning the overall operation of the waste treatment plant.

## PROCEDURES USED IN COLLECTING WASTE SAMPLES

### Grab Samples

Grab samples, which may be required to overcome rapid changes in sewage, are generally taken for the following tests: dissolved oxygen (DO), pH, chlorine demand, residual chlorine, settleable solids, and relative stability. They are also used to determine the concentration of mixed liquor and the concentration of sludge in the "activated sludge process," for monthly tests for digester contents, and for stream surveys.

### Composite Samples

A very important step of composite sampling is to insure that the samples are collected at regular intervals over a selected time period e.g., hourly, each half-hour, etc. A composite sample is generally taken for the determination of suspended solids, total biochemical oxygen demand (BOD), total and volatile solids of sludge and grease.

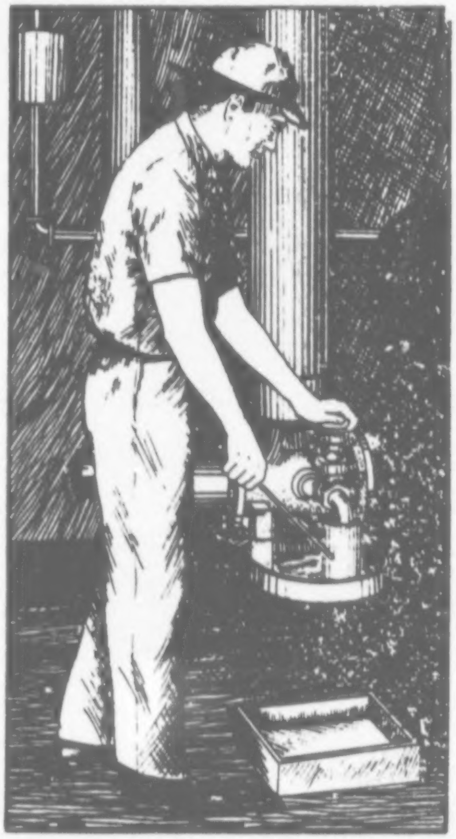


Figure 2. Collection of Composite Sludge Samples

Composite sludge samples taken from raw sludge going to a digester, or digested sludge going to drying beds should be made up of individual samples collected at regular intervals over the pumping or drawoff period. Space these intervals to provide for the collection of at least five or six individual samples over any one period. The composite sample must represent all pumping periods for the entire day. The method of collecting sludge samples is shown in figure 2.

### Sewage and Effluent Samples

Take samples of flowing sewage or effluent from channels at two-thirds the depth of flow and at a point free from back eddies. Figure 3 shows the design of a sludge and an effluent sampler. Another common type of sampler is shown in figure 4. Samples may be taken from such places as a channel, see figure 5, or from a tank ahead of the overflow weir, see figure 6.

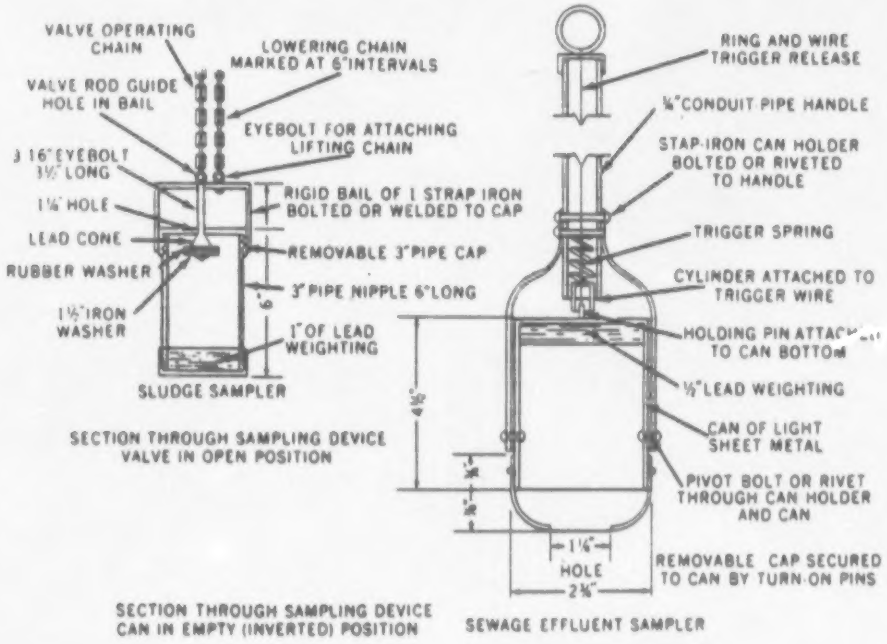

VALVE OPERATING CHAIN
LOWERING CHAIN MARKED AT 6" INTERVALS
VALVE ROD GUIDE HOLE IN BAIL
EYEBOLT FOR ATTACHING LIFTING CHAIN
3 16" EYEBOLT 3½" LONG
1¼" HOLE
RIGID BAIL OF 1 STRAP IRON BOLTED OR WELDED TO CAP
LEAD CONE
REMOVABLE 3" PIPE CAP
RUBBER WASHER
3" PIPE NIPPLE 6" LONG
6"
1½" IRON WASHER
1" OF LEAD WEIGHTING
SLUDGE SAMPLER
SECTION THROUGH SAMPLING DEVICE VALVE IN OPEN POSITION
RING AND WIRE TRIGGER RELEASE
¼" CONDUIT PIPE HANDLE
STAP IRON CAN HOLDER BOLTED OR RIVETED TO HANDLE
TRIGGER SPRING
CYLINDER ATTACHED TO TRIGGER WIRE
HOLDING PIN ATTAC
TO CAN BOTTOM
½" LEAD WEIGHTING
4½"
CAN OF LIGHT SHEET METAL
¾"
½"
PIVOT BOLT OR RIVET THROUGH CAN HOLDER AND CAN
1¼"
HOLE
2¾"
REMOVABLE CAP SECURED TO CAN BY TURN ON PINS
SECTION THROUGH SAMPLING DEVICE CAN IN EMPTY (INVERTED) POSITION
SEWAGE EFFLUENT SAMPLER

Figure 3. Samplers Designed for Collecting Sewage and Sludge

### Dissolved Oxygen Samples

Samples for dissolved oxygen tests must be taken carefully with special apparatus to prevent increasing the oxygen content by contact with air. Narrow mouth 8 ounce bottles with glass stoppers should be used with the sampling device. See figure 7.

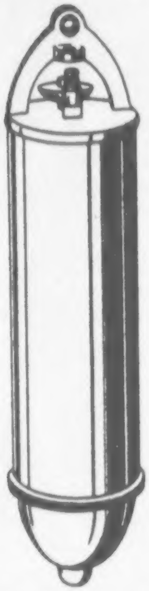


Figure 4. Sewage and Effluent Sampler

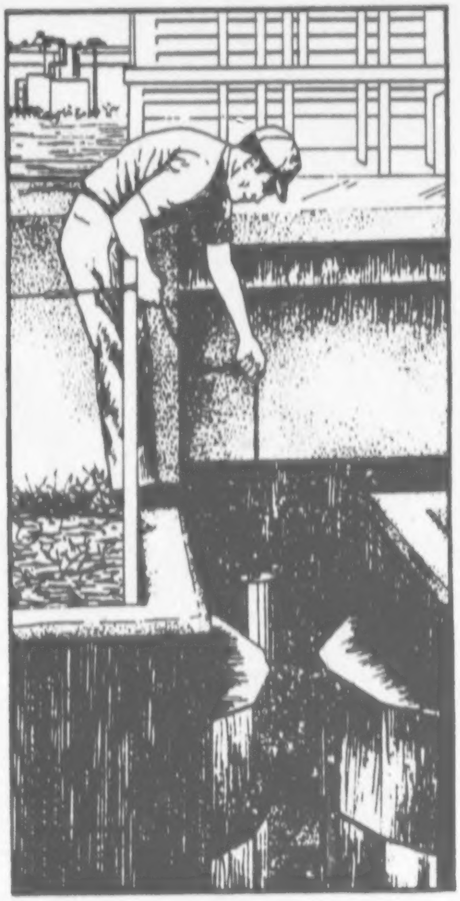


Figure 5. Sample Taken

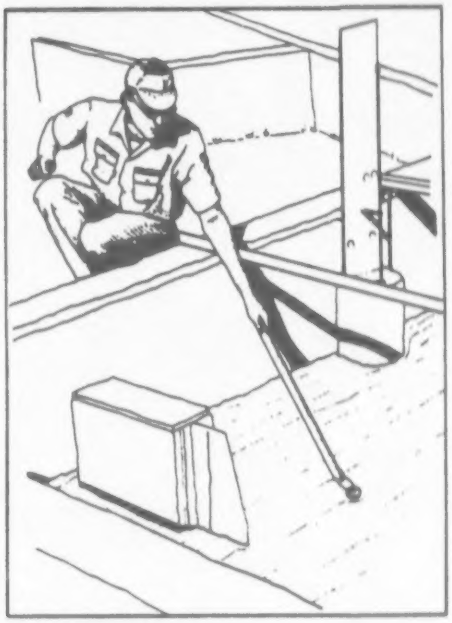


Figure 6. Sampling from Tank Ahead of Weir

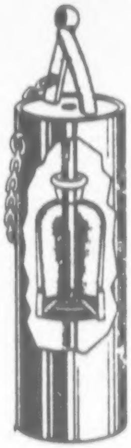


Figure 7. Device for Taking Dissolved Oxygen Samples

### Sludge Samples

Sludge samples may be taken from a digester by the device shownin figure 4. Its use in the sampling hole of a digestion tank is illustrated in figure 8. The chain is marked to indicate depth at one-foot intervals. Collect samples of digester sludge at intervals of 3 to 5 feet, starting at the top and working down to avoid agitating the lower sludge from which the subsequent samples are taken. Pour each sample into a wide mouth bottle, appropriately marked, and rinse the sampler thoroughly before each s sample is taken. A pitcher pump with a hose marked at one-foot intervals may also be used.

## SUMMARY

A water sample should be collected so that it represents what it is supposed to represent. It should not be diluted, concentrated, or contaminated before testing. Samples should be labeled so that they do not become mixed up and so that the report may be sent to the right place.

Measuring the impurities in sewage is very important in the operation of a sewage plant. To be able to make these measurements, it is necessary to be careful in both collecting the sample and in making the tests.

There are two types of samples in sewage tests. They are grab samples and composite samples. The grab sample gives an indication of conditions at any one time. It is also used for test results where the passage of time increases the inaccuracy of a test. The settleable solids test is one test requiring a grab sample. The composite sample is taken at different times and gives results for an average set of conditions. The total solids, suspended solids, and also the dissolved solids tests all require a composite sample.

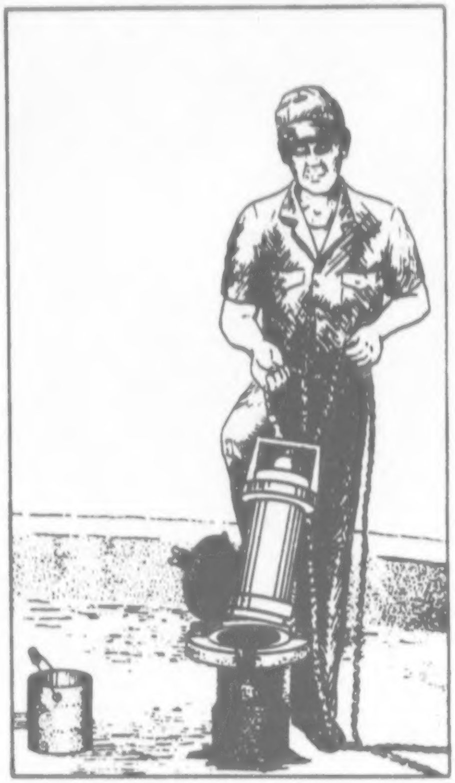


Figure 8. Collection of Sludge Sample from Digester

## QUESTIONS

1. What is the biggest problem in obtaining a water sample?

2. What type of bottle is used as a container for a water sample?

3. Name two precautions which should be observed to prevent a water sample from becoming contaminated by the atmosphere.

4. Why should samples be labeled as soon as they are taken?

5. Where should a water sample be taken from a water supply well?

6. What are grab samples?

7. Which tests require composite samples?

8. Where are samples taken from flowing sewage?

9. What is a composite sample?

## REFERENCES

1. AFM 85-13, Maintenance and Operation of Water Plants and Systems
2. Boiler Feed and Boiler Water Softening - Blanning and Rich
3. Water Treatment and Purification - Ryan
4. AFM 85-14, Maintenance and Operation of Sewage and Industrial Waste Plants
5. Standard Methods, 10th Edition

## WATER ANALYSIS

### OBJECTIVE

This study guide is to present the more commonly used water tests that are performed at water plants.

### INTRODUCTION

The Air Force water supply varies greatly over the face of the world and each installation has its own differences in water characteristics. The water tests you perform in this unit of instruction will enable you to perform almost any test required of you, whether you be in Japan, Spain, or stateside.

## PURPOSE OF WATER ANALYSIS

When a site is selected as a water source, the water must be analyzed to determine how the finished product will taste. Analysis will also show what type of treatment is necessary and the chemicals required.

At old established water plants, a periodic analysis will determine if the plant is operating efficiently, that is, if enough or too many chemicals are being added.

Industrial water used in heating, cooling units, boilers, aircraft, radiators, etc. must be analyzed often so as not to damage expensive equipment.

## METHODS USED IN ANALYSIS

Water analysis can be broken down into four methods of testing: gravimetric, volumetric, colorimetric, and the use of electric meters. You will find a full explanation of each test in the manual you will use.

### Gravimetric

This is a test that uses weights and balances. If you measure the weight of a container of dirty water, you can then evaporate all the water and again weigh the container with the dirt in the bottom. You can easily determine the weight of the dirt. This is a gravimetric analysis.

### Volumetric

This method of analysis is based on pouring a small amount of chemical into the unknown water sample and watching for a reaction. This is explained in the 563X0, Career Ladder Laboratory Manual in the "Titration (Volumetric), Procedures for,"

### Colorimetric

This method of testing is quite simple and the one you may use often. In this test, you add one or more chemicals to a sample of water and watch for a color change.

Electric Meters

This method of testing is becoming quite popular because of the ease of use and the accuracy obtained. You use this method in testing water for pH and specific conductance.

## ANALYSIS PERFORMED

In this course of instruction, you will perform those analyses that you will perform at your next assignment. You will be given a laboratory manual. This manual will explain the step-by-step procedures for each method of water analysis. The analyses you will do in this course:

- Temperature
- Turbidity
- Color
- Chlorine residual
- pH
- Hardness
- Alkalinity
- Dissolved oxygen
- Dissolved iron
- Dissolved fluoride
- Phosphate
- Jar test

## SUMMARY

Water analysis is necessary when the purity or treatment procedures are in question. Analysis procedures can be divided into four methods: gravimetric, volumetric, colorimetric, and the use of electric meters.

## QUESTIONS

1. Name three reasons for performing water analysis.

2. What is industrial water?

3. Balances and scales are used in which method of testing?

4. In which water analysis is the volumetric method used?

5. Name two analyses using electric meters.

## REFERENCES

SG 3ABR56330-II-6, Water Analysis

563X0, Career Ladder Laboratory Manual

AFM 85-13, Maintenance and Operation of Water Plants and Systems

## WASTEWATER ANALYSIS

### OBJECTIVE

The purpose of this study guide is to help you to understand and become familiar with the analyses which are required to gain the necessary information for proper operation of the waste disposal plant for the base.

### INTRODUCTION

The term "wastewater," as used in this study guide, refers to the spent water of a base or community containing the wastes from domestic uses plus some industrial wastes, which are collected in the sanitary sewer system and flows through the waste disposal plant and is discharged into a receiving stream. On an average it is 99.9% (by weight) water. The remaining 0.1% contains the wastes produced in human habitations and consists of excrements, dirt from the laundry, dishwater and other household wastes, plus varying amounts of industrial wastes. It is frequently termed "sanitary sewage," a term indicating origin rather than condition.

The purpose of wastewater treatment is to remove the suspended solids and to reduce the biological oxygen demand to a level which will not deplete the dissolved oxygen from the receiving stream. It should be noted that the treatment does not remove the dissolved inorganic materials such as chlorides, sulfates, and phosphates from the water.

The purposes of the wastewater tests are to determine the degree of treatment required to control the operation of treatment procedures, and to determine the efficiency and/or adequacy of the treatment, as shown by the quality of the effluent.

Information pertaining to wastewater analysis will be presented under the following main headings:

* CHARACTERISTICS AND STRENGTH OF WASTEWATER
* DETERMINATION OF THE SOLIDS CONTAINED IN WASTEWATER
* DETERMINATION OF THE BIOCHEMICAL OXYGEN DEMAND
* DETERMINATION OF RELATIVE STABILITY

This study guide does not contain all of the information that you should know about the analysis of wastewater and the study of the additional material which is listed in the references at the end of the study guide is recommended.

## CHARACTERISTICS AND STRENGTH OF WASTEWATER

The characteristics of both treated and untreated wastewater, which may be determined by inspection or by tests, include color, odor, B.O.D., relative stability, pH, temperature, total solids, rate of settling, and strength or quality.

Fresh sanitary sewage is normally gray in color, having somewhat the odor and appearance of dirty dishwater. Stale or "septic" sanitary sewage is dark to black in color with varying intensities of disagreeable odors. The change from fresh to septic sewage results from the action of bacteria present in the organic material which is contained in the sewage. The waste products in wastewater consist of both organic and inorganic materials which may be in the form of either suspended or dissolved solids. It is the organic matter which gives sewage its objectionable properties, and it is the decomposition of this material by bacteria that results in the formation of septic sewage. The organic matter may be stable, meaning that it is resistant to bacterial breakdown, or it may be unstable and breakdown easily.

The terms weak, medium, or strong are used to describe the strength of sewage. The concentration of waste materials included will determine which term should be used. See Table 1 for conditions which have been designated as being either weak, medium, or strong.

| Analysis | Weak | Medium | Strong |
|---|---|---|---|
| Total Solids | 430 | 720 | 1200 |
| Total Volatile Solids | 240 | 420 | 810 |
| Suspended Solids | 100 | 200 | 370 |
| Volatile Suspended Solids | 70 | 130 | 220 |
| Settleable Solids, mg/l. | 2 | 4 | 6 |
| Biochemical Oxygen Demand | 100 | 210 | 410 |
| Total Nitrogen | 10 | 30 | 40 |
| Ammonia Nitrogen | 4 | 10 | 20 |
| Soaps and Fats | 6 | 10 | 20 |

Table 1. Average Composition of Various Strength Sewage at Military Installations, Expressed in mg/l (ppm).

## DETERMINATION OF THE SOLIDS CONTAINED IN WASTEWATER

### Total Solids

The total solids include all of the dissolved solids plus all of the suspended solids contained in the wastewater. The total solids are normally expressed as mg/l (milligrams per liter). To determine the amount of total solids it is necessary to evaporate a known volume of well mixed wastewater to dryness at a constant temperature of 103° - 105° C. in a previously weighed dish, then re-weigh the dish containing the dry residue and calculate the gain in weight. The gain in weight may be easily converted to mg/l.

Not all of the total solids are removed from wastewater by treatment received in the wastewater treatment plant, as a large part of the soluable solids, which comprise the largest part of total solids, pass through the treatment devices unchanged.

One of the reasons for making the total solids test is to gain part of the information needed to calculate the dissolved solids content of wastewater.

### Suspended Solids

The suspended solids in wastewater are the solids which can be filtered out of a known volume of sample in a previously weighed Gooch crucible with an asbestos filter pad, or other suitable filtering device. The sample should be well mixed prior to measuring out the correct volume for test purposes. The weight gain of the Gooch crucible indicates the amount of suspended solids present. It should be noted that suspended solids includes the solids that would settle out of the wastewater when the carrying stream loses its velocity, plus matter that is too light to settle but which is trapped by the filter pad. This test is useful in evaluating the efficiency of plant units. The overall removal in complete treatment is usually more than 90%.

### Dissolved Solids

The amount of dissolved solids may be computed by subtracting the amount of suspended solids from the amount of total solids. This information is not normally required; however, it may be used to determine the character of raw wastewater or to show a high rate of industrial pollution. See figure 1 for classification of solids in a typical sanitary sewage system.

### Settleable Solids

A test has been devised to measure accurately the amount of solids which will settle out. The tests may be made by using an Imhoff cone which is a piece of laboratory equipment named in honor of Dr Karl Imhoff, the inventor of the Imhoff tank. This cone must be filled with well mixed wastewater to the one liter mark. The cone and its contents are allowed to stand for two hours after which the amount of settleable solids may be read directly in milliliters. The settleable solids may be expressed either as a quantity by weight or by volume--most frequently on a volume basis. By testing both the influent and effleunt of a sedimentation tank, the percentage of solids removal and efficiency of tank may be found.

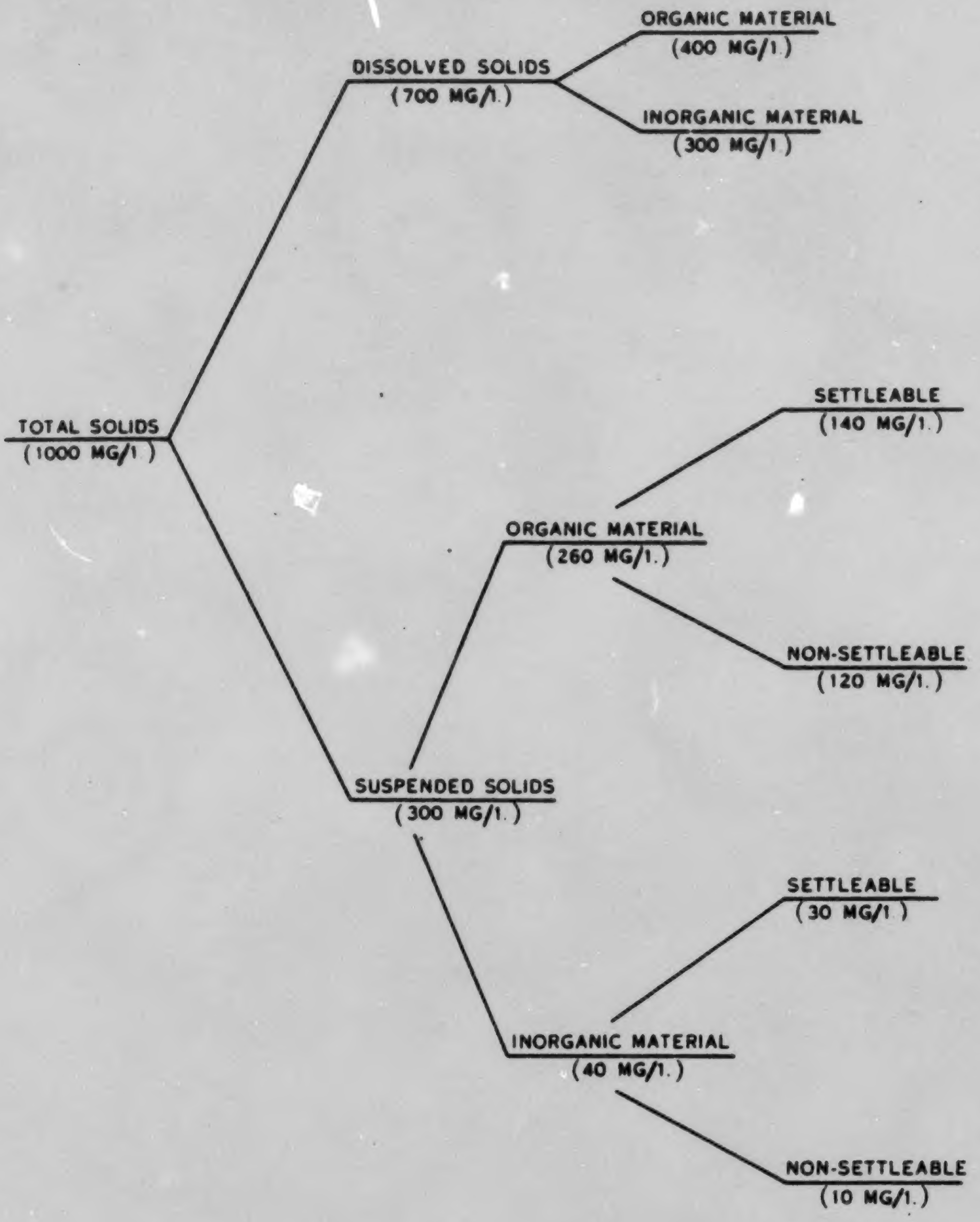

ORGANIC MATERIAL
(400 MG/1.)
DISSOLVED SOLIDS
(700 MG/1.)
INORGANIC MATERIAL
(300 MG/1.)
SETTLEABLE
(140 MG/1.)
TOTAL SOLIDS
(1000 MG/1.)
ORGANIC MATERIAL
(260 MG/1.)
NON-SETTLEABLE
(120 MG/1.)
SUSPENDED SOLIDS
(300 MG/1.)
SETTLEABLE
(30 MG/1.)
INORGANIC MATERIAL
(40 MG/1.)
NON-SETTLEABLE
(10 MG/1.)

Figure 1. Total Solids Contained in a Typical Sanitary Sewage System. (Engineering Extension Service, Texas A&M University, Sewage Works Operation Training Manual, Unit 1.)

### Volatile Solids

It is desirable to determine how much of the total solids are made up or organic or "volatile" matter and how much is mineral or "fixed" matter. This may be accomplished by carefully igniting or burning the residue from the total solids test and noting the loss in weight which is called volatile matter. This test measures the amount of solids that vaporize at 600°C. Most organic compounds vaporize below 600°C, while most inorganic compounds must be heated in excess of 600°C before they will volatize. In practice, the volatile matter is sometimes expressed in percentage by weight of the total amount of solids, either total solids or suspended solids. The reason why the amount of organic matter should be known is that the sewage treatment concerns organic matter while mineral matter is of secondary importance.

## BIOCHEMICAL OXYGEN DEMAND (B. O. D.)

The most important test that is normally performed on wastewater, and the one giving the most information on the strength of the sewage, is the B. O. D. text. As the name implies, it is the quantity of oxygen required for the biochemical oxidation in a given period of time, and at a given temperature, normally for 5 days with the temperature of 20°C. The B. O. D. test utilizes oxygen from the air which has been dissolved in water. This condition simulates the conditions encountered in sewage purification, which is why the test is so valuable.

In making the test, a known volume of wastewater is mixed with a measured amount of water containing a predetermined amount of oxygen. The mixture is placed in a glass-stoppered bottle and kept at the proper temperature for the specified number of days. Under these conditions, the sewage bacteria which are normally present will cause the organic matter to become oxidized. Oxygen will be used up in direct proportion to the amount of organic matter which is present. The decomposition products formed are mostly carbon dioxide ($CO_2$) and water ($H_2O$). At the end of the specified period, the amount of oxygen remaining in the mixture is determined, and from the difference between the original and the final oxygen content, the B. O. D. can be calculated. The B. O. D. test is considered to be a direct measurement of the strength of the sewage. A B. O. D. of 95 ppm or less indicates weak sewage while a B. O. D. of 400 ppm or above indicates strong sewage.

## RELATIVE STABILITY

The organic matter in wastewater may be stable or unstable. The stable compounds are fairly resistant to bacterial breakdown, while the unstable compounds are not. It should be noted that one of the objectives of sewage treatment is to stabilize the organic matter by oxidation, that is to "burn it up" chemically.

Sewage will putrefy or become septic due to bacterial action and a lack of oxygen. The susceptibility of sewage to putrefy is known as putrecibility, and the test to indicate this characteristic is known as the "relative stability" test. The test consists in the addition of a specified amount of a blue dye known as Methylene Blue to a sample of sewage and noting the number of days required for the blue color to fade out and disappear. The test is based on the fact that when the oxygen in wastewater has been completely depleted, hydrogen sulfide is formed by the action of anerobic bacteria. In the presence of oxygen the dye retains its color. When the hydrogen sulfide is formed, the dye is broken down chemically and the blue color disappears.

The length of time required for the decolorization of the sample is a measure of the relative stability of the wastewater sample. The percentage of relative stability must be taken from charts. When the color disappears in one day, the relative stability is 21%; if only two days are required, 37%; if three days, 50%; four days, 60%, and five days, 68%. The relative stability test is used extensively as a guide to the character of treated or partially treated wastewater.

## SUMMARY

The purpose for performing the analysis of wastewater samples is to determine the operating efficiency of the waste disposal plant. Tests are performed on plant influent, the various stages of treatment, and on the plant effluent. The tests commonly performed include total solids, suspended solids, settleable solids, volatile solids, B. O. D., and relative stability. The pH and temperature may also be determined. It has been stated that the B. O. D. (biological oxygen demand) is the most important test performed on wastewater.

## QUESTIONS

1. What is the purpose of wastewater treatment?
2. What are the distinguishing characteristics of wastewater?
3. Which terms are used to describe the strength of wastewater?
4. What are the two principal types of solids contained in total solids?
5. How are the total solids determined on a sample of wastewater?
6. Which of the wastewater tests required the use of an Imhoff cone?
7. How can you determine the amount of organic matter in a wastewater sample?
8. Which is the best test for indicating the overall efficiency of the waste disposal plant?
9. Where would you collect a sample of wastewater for performing the relative stability test?
10. What determines how soon the blue color disappears in the relative stability test?

## REFERENCES

1. Manual for Sewage Plant Operators, Prepared by Texas Water and Sewage Works Assoc.
2. Principles of Sewage Treatment, Published by The National Lime Association, Washington, D.C.
3. Sewage Treatment, Unit II, Published by Engineering Extension Service, Texas A & M University.

WORKBOOKS 3ABR56330-II-1-P1 Thru 6-P2

Department of Civil Engineering Training

17-4

Environmental Support Specialist

# WATER AND WASTEWATER ANALYSIS

February 1972

SHEPPARD AIR FORCE BASE

**Designed For ATC Course Use**

**DO NOT USE ON THE JOB**

Dept of Civil Engineering Tng
Sheppard AFB, Texas

WB 3ABR56330-II-1-P1
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## INTRODUCTION TO BASIC CHEMISTRY

### OBJECTIVE

The purpose of this exercise is to aid you in developming a better understanding of chemical symbols, formulas, and equations.

### IDENTIFYING CHEMICAL FORMULAS OF IONS

Enter the chemical symbol beside each of the following elements. (Reference should be made to table 1.)

1. Hydrogen ________
2. Oxygen ________
3. Sodium ________
4. Magnesium ________
5. Calcium ________
6. Chlorine ________
7. Carbon ________
8. Iron ________
9. Potassium ________
10. Barium ________
11. Aluminum ________
12. Fluorine ________

### IDENTIFYING CHEMICAL FORMULAS OF IONS

Write the chemical formula for each of the following ions. Show the positive or negative charges. (Reference should be made to table 1.)

1. Ammonium ________
2. Hydroxal ________
3. Calcium ________
4. Magnesium ________
5. Carbonate ________
6. Bicarbonate ________
7. Sodium ________
8. Sulfate ________
9. Sulfite ________
10. Iron (Ferric) ________
11. Chloride ________
12. Manganese ________

13. Iron (Ferrous) ____________
14. Fluoride ____________
15. Hydrogen ____________
16. Phosphate ____________
17. Aluminum ____________
18. Nitrate ____________
19. Potassium ____________
20. Copper ____________

## IDENTIFYING IONS

Write the name of the following ions. (Reference should be made to table 1.)

1. $Ca^{++}$ ____________
2. $Cl^{-}$ ____________
3. $CO_3^{--}$ ____________
4. $Mg^{++}$ ____________
5. $SO_4^{--}$ ____________
6. $Fe^{++}$ ____________
7. $Al^{+++}$ ____________
8. $PO_4^{---}$ ____________
9. $H^{+}$ ____________
10. $OH^{-}$ ____________
11. $Na^{+}$ ____________
12. $K^{+}$ ____________

## IDENTIFYING CHEMICAL FORMULAS OF COMPOUNDS

1. Sodium bicarbonate ____________
2. Sodium carbonate ____________
3. Sodium chloride ____________
4. Calcium bicarbonate ____________
5. Calcium carbonate ____________
6. Calcium chloride ____________
7. Calcium phosphate ____________
8. Magnesium carbonate ____________
9. Magnesium hydroxide ____________
10. Hydrogen sulfate ____________
11. Hydrogen chloride ____________
12. Hydrogen phosphate ____________
13. Hydrogen carbonate ____________
14. Disodium hydrogen $PO_4$ ____________
15. Potassium hydroxide ____________
16. Potassium sulfite ____________
17. Potassium chloride ____________
18. Aluminum sulfate ____________
19. Aluminum hydroxide ____________
20. Aluminum phosphate ____________
21. Carbon oxide ____________
22. Calcium oxide ____________
23. Ferrous oxide ____________
24. Ferric oxide ____________

25. Silicon dioxide ________________
26. Zinc Carbonate ________________
27. Magnesium bromite ________________
28. Barium carbonate ________________
29. Sulfuric aicd ________________
30. Hydrochloric acid ________________
31. Carbonic acid ________________
32. Hydrogen fluoride ________________
33. Silicon fluoride ________________
34. Ammonium hydroxide ________________
35. Silver nitrate ________________
36. Barium carbonate ________________
37. Ferric chloride ________________
38. Ferric sulfate ________________
39. Ferric hydroxide ________________
40. Ferrous hydroxide ________________

## SOLVING FOR CHEMICAL REACTION

1. Write the balanced equation opposite each of the following double displacement equations. In this type of reaction, think of the positive ions changing places in the two original compounds. This will result in two new compounds.

   a. Silver nitrate + potassium chloride

   $AgNO_3 + KCl \longrightarrow$ ________________ + ________________

   b. Copper sulfate + barium chloride

   $CuSO_4 + BaCl \longrightarrow$ ________________ + ________________

   c. Ammonium chloride + sodium hydroxide

   $NH_4Cl + NaOH \longrightarrow$ ________________ + ________________

   d. Ammonium sulfate + calcium hydroxide

   $(NH_4)_2SO_4 + Ca(OH)_2 \longrightarrow$ ________________ + ________________

   e. Potassium hydroxide + hydrochloric acid

   $KOH + HC1 \longrightarrow$ ________________ + ________________

   f. Calcium hydroxide + sulfuric acid

   $Ca(OH)_2 + H_2SO_4 \longrightarrow$ ________________ + ________________

2. Finish balancing the following equations. In this type of reaction, the ions switch to form new compounds.

   a. Silver nitrate + potassium chloride

$AgNO_3 + KCl$ = ____________ + ____________

b. Copper sulfate + barium chloride

$CuSO_4 + BaCl_2$ = ____________ + ____________

c. Ammonium chloride + sodium chloride

________ + ____________ = ____________ + ____________

d. Ammonium sulfate + calcium hydroxide

________ + ____________ = ____________ + ____________

e. Potassium hydroxide + hydrohloric acid

________ + ____________ = ____________ + ____________

f. Calcium hydroxide + sulfuric acid

________ + ____________ = ____________ + ____________

g. Sodium sulfate + zinc nitrate

________ + ____________ = ____________ + ____________

h. Aluminum sulfate + calcium hydroxide

________ + ____________ = ____________ + ____________

i. Barium hydroxide + sulfuric acid

________ + ____________ = ____________ + ____________

j. Copper sulfate + sodium chloride

________ + ____________ = ____________ + ____________

k. Aluminum hydroxide + phosphoric acid

________ + ____________ = ____________ + ____________

l. Magnesium carbonate + calcium hydroxide

________ + ____________ = ____________ + ____________

3. Finish balancing the following single displacement reactions. Refer to table 2 to see if a reaction takes place. If no reaction takes place, write the letters N.R. Equation one is completed in full. Note that a metal in its element form is neutral in valence.

a. Metallic zinc in a solution of lead nitrate

$Zn$ + $Pb(NO_3)_2$ = $Zn(NO_3)_2$ + $Pb$

b. Lead in a solution of zinc nitrate

__________ + __________ = __________ + __________

c. Iron in a solution of copper sulfate

__________ + __________ = __________ + __________

d. Copper in a solution of silver nitrate

__________ + __________ = __________ + __________

e. Magnesium in a solution of copper sulfate

__________ + __________ = __________ + __________

| CATIONS (Positive Ions) | | ANIONS (Negative Ions) | |
|---|---|---|---|
| SUBSTANCE | FORMULA VALENCE | SUBSTANCE | FORMULA VALENCE |
| Sodium | $Na+$ | Bromide | $Br-$ |
| Potassium | $K+$ | Chloride | $Cl-$ |
| Hydrogen | $H+$ | Fluoride | $F-$ |
| Ammonium | $NH_4+$ | Hydroxal | $OH-$ |
| Silver | $Ag+$ | Nitrate | $NO_3-$ |
| Barium | $Ba++$ | Bicarbonate | $HCO_3-$ |
| Calcium | $Ca++$ | Carbonate | $CO_3--$ |
| Magnesium | $Mg++$ | Oxygen | $O--$ |
| Copper | $Cu++$ | Sulfate | $SO_4--$ |
| Zinc | $Zn++$ | Sulfite | $SO_3--$ |
| Manganese | $Mn++$ | Sulfide | $S--$ |
| Iron (ferrous) | $Fe++$ | Phosphate | $PO_4---$ |
| Iron (ferric) | $Fe+++$ | | |
| Aluminum | $Al+++$ | | |
| Carbon | $C++++$ | | |
| Silicon | $Si++++$ | | |

Table 1. Chemical Data

## POSITIVE CHART

Lithium (Li)
Potassium (K)
Calcium (Ca)
Sodium (Na)
Magnesium (Mg)
Aluminum (Al)
Manganese (Mn)
Zinc (Zn)
Chromium (Cr)
Iron (Fe)
Tin (Sn)
Lead (Pb)
Hydrogen (H)
Copper (Cu)
Mercury (Hg)
Silver (Ag)
Platinum (Pt)
Gold (Au)

## RULES

1. With reference to the above chart, any element which appears above another element will replace the lower element from its compound.
2. With reference to the above E.M.F. Series, any element which appears below another element will not replace the high element from its compound.

Table 2. Electra Motive Force (EMF) Series Chart

## TESTING FOR ACIDS, BASES, AND SALTS

## OBJECTIVE

The purpose of this exercise is to assist you in gaining a better understanding of bases, radicals, acids, and salts.

## DETERMINING REACTION OF ACIDS, BASES, AND SALTS

1. In the blank space beside each of the following bases, write their chemical formulas.

   a. Sodium hydroxide ____________________

   b. Calcium hydroxide ____________________

   c. Aluminum hydroxide ____________________

   d. Magnesium hydroxide ____________________

2. In the blank space beside each of the following salts, write their chemical formulas.

   a. Calcium chloride ____________________

   b. Calcium bicarbonate ____________________

   c. Sodium bicarbonate ____________________

   d. Calcium sulfate ____________________

   e. Magnesium sulfate ____________________

3. In the blank space beside each of the following acids, write their chemical formulas.

   a. Hydrochloric acid ____________________

   b. Sulfuric acid ____________________

c. Phosphoric acid

d. Carbonic acid

4. Perform the following experiment to observe the corrosive effect of acid on metals.

   a. Measure 50 ml of 1:1 hydrochloric acid (HCl) solution in a graduated cylinder and pour into 250-ml beaker.

   CAUTION: Extreme care should be exercised while performing this experiment because HCl may cause very serious burns to the skin and damage the clothing.

   b. Carefully place the metal samples, provided by the instructor, into the acid solution.

   c. Observe the release of hydrogen gas from some of the samples (Zn + Fe).

   d. Set aside for 30 minutes, then pour off the acid and wash the samples in water. Observe the degree of corrosion.

   e. Record results:

|  | METAL | RESULTS |
|---|---|---|
| (1) |  |  |
| (2) |  |  |
| (3) |  |  |
| (4) |  |  |

   f. Rinse and clean test equipment.

5. Observe the formation of salt as a result of mixing an acid and base.

   a. Pour 50 ml of sodium hydroxide solution (NaOH) into a 50-ml beaker.

   b. Slowly, pour 50 ml of hydrochloric acid (HCl) into the sodium hydroxide solution to form a salt solution.

$$NaOH + HCl \qquad\qquad NaCl + H_2O$$

CAUTION: If the mixing rate is fast, there is a possibility of breaking the beaker from the heat generated in the chemical reaction.

c. Boil the solution in a beaker until the water evaporates, leaving sodium chloride crystals on the bottom of the beaker.

d. Allow the beaker to cool and then rinse the equipment in distilled water.

Dept of Civil Engineering Training
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# DEFINITION OF CHEMICAL TERMS

OBJECTIVE:

The purpose of this exercise is to aid you in learning the definitions of elements, symbols, radicals, and formulas.

INSTRUCTIONS: Place the letter identifying the correct term in the blank space preceding the definitions in Column I.

COLUMN I

1. ( ) Anything that has weight, or mass, and occupies space.
2. ( ) Radicals.
3. ( ) Science pertaining to reactions of elements and compounds.
4. ( ) Formulas.
5. ( ) Compounds composed of carbon and hydrogen.
6. ( ) Symbol.
7. ( ) Any identifiable kind of matter.
8. ( ) Ratio of the weight of any solution to the weight of the same volume of water.
9. ( ) Smallest particle of an element.
10. ( ) A solution containing all the solute it will dissolve at that particular temperature.
11. ( ) Any compound which releases $H^+$ ions when dissolved in water.
12. ( ) A substance composed of only one kind of atom.
13. ( ) A solution containing a large amount of solute per unit volume.
14. ( ) A substance which has been dissolved.
15. ( ) A substance which will dissolve another substance.

COLUMN II

a. Solute
b. $CO_3$, $SO_4$, $PO_4$
c. Solvent
d. Chemistry
e. Ca, Mg, Na, H & O
f. Matter
g. $CuCl_2$, $MgSO_4$, $NaHCO_3$
h. Organic matter
i. Acid
j. Substances
k. Specific gravity
l. Concentrated solution
m. Saturated solution
n. Element
o. Atom

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16. ( ) A uniform mixture of two or more substances in liquid form.

17. ( ) An element which is classed as a nonmetal.

18. ( ) May be identified by its peculiar luster.

19. ( ) The process by which molecules break up to form ions.

20. ( ) A single letter used to represent the name of an element.

21. ( ) A number which shows the comparative weight of one atom.

22. ( ) A number which shows the number of protons contained in one atom.

23. ( ) The relative combining capacity of an element.

24. ( ) The weight of an element which will react chemically with another element.

25. ( ) A substance composed of two or more elements which are combined chemically (no charge).

26. ( ) Any compound which releases OH ions when dissolved in water.

27. ( ) An ion composed of two or more elements combined chemically.

28. ( ) Small particle with a (+) charge.

29. ( ) Small particle with a (-) charge.

30. ( ) Atom or radical with an electrical charge.

31. ( ) Ion with a (+) charge.

32. ( ) Weight of one molecule of a compound.

33. ( ) Smallest part of a compound.

34. ( ) Abbreviation for the name of a compound.

35. ( ) An ion with a (-) charge.

p. Anion

q. Symbol

r. Atomic number

s. Atomic weight

t. Valence

u. Equivalent weight

v. Sulfur

w. Metal

x. Ionization

y. Proton

z. Molecular weight

aa. Molecule

bb. Formula

cc. Compound

dd. Radical

ee. Electron

ff. Ion

gg. Cation

hh. Base

ii. Solution

Dept of Civil Engineering Tng
Sheppard AFB, Texas

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# AIR FORCE WATER REQUIREMENTS

## OBJECTIVE

The purpose of this workbook is to help you develop a better understanding of water requirements in the Air Force.

## PROCEDURES

1. Using the list of terms below, indicate whether the water is considered domestic water or industrial water:

    a. Drinking water ____________________

    b. Laundry purposes ____________________

    c. Cooling tower water ____________________

    d. Bathing purposes ____________________

    e. Mixing medicine ____________________

    f. Jet engine demineralized water ____________________

    g. Swimming pools ____________________

    h. Boiler water ____________________

    i. Fire fighting ____________________

    j. Tree and grass watering ____________________

2. Define these terms:

    a. Effective population ______________________________________

    ____________________________________________________________

    b. Authorized population ______________________________________

    ____________________________________________________________

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3. List six methods of recognizing water waste.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

## COMMON IMPURITIES IN WATER SUPPLIES

### OBJECTIVE

The purpose of this exercise is to aid you in developing a better understanding of the common impurities found in water, their causes, and their effects.

### DETERMINING RELATIONSHIP OF WATER IMPURITIES

In the chart below, indicate whether the impurities listed are normally found in low or high amounts by comparison of ground and surface water.

| | TDS | Suspended Solids | Dissolved Gases | Biological Organisms | Turbidity | Ca | Fe |
|---|---|---|---|---|---|---|---|
| Ground | | | | | | | |
| Surface | | | | | | | |

### CLASSIFICATION OF WATER IMPURITIES

Under the general classification of impurities listed below, list some of the causes of such impurities.

1. Turbidity
   a. ____________
   b. ____________
   c. ____________
2. Color
   a. ____________
   b. ____________
   c. ____________
3. Alkalinity
   a. ____________
   b. ____________
   c. ____________

4. **Hardness**

a. ________________

b. ________________

c. ________________

5. **Dissolved gases**

a. ________________

b. ________________

c. ________________

## CALCULATING pH

**Using the pH scale listed below, complete the following questions.**

**1 2 3 4 5 6 7 8 9 10 11 12 13 14**

________________ ________________________

1. **Which range above indicates alkalinity?** ________________
2. **Which range above indicates acidity?** ________________
3. **A neutral pH would be one having a pH value of** ________________.
4. **Would the addition of sulfuric acid increase or decrease the pH value?**

   ____________________
5. **Encircle the pH value that would be the most corrosive.**

   **6.7 8.2 6.4 8.8 9.1**

## COMMON IMPURITIES FOUND IN WATER

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| Turbidity | None - expressed in analysis as $SiO_2$. | Imparts unsightly appearance to water. Deposits in water lines, process equipment, boilers, etc. Interferes with most process uses. | Coagulation, settling and filtration. |
| Color | None - expressed in analysis as "units" of color on arbitrary scale. | May cause foaming in boilers. Hinders precipitation methods such as iron removal, hot phosphate softening. Can stain product in process use. | Coagulation and filtration. Chlorination. Adsorption by activated carbon. |
| Hardness | Calcium and magnesium salts expressed as $CaCO_3$. | Chief source of scale in heat exchange equipment, boilers, pipe lines, etc. Forms curds with soap, interferes with dyeing, etc. | Softening. Distillation. Internal boiler water treatment. Surface active agents. |
| Alkalinity | Bicarbonate ($HCO_3$), carbonate ($CO_3$), and hydrate (OH), expressed as $CaCO_3$. | Foaming and carryover of solids with steam. Embrittlement of boiler steel. Bicarbonate and carbonate produce $CO_2$ in steam, a source of corrosion. | Lime and lime-soda softening. Acid treatment. Hydrogen zeolite softening. Demineralization. Dealkalization by anion exchange. Distillation. |
| Free Mineral Acid | $H_2SO_4$, HCl, etc, expressed as $CaCO_3$. | Corrosion. | Neutralization with alkalies. |
| Carbon Dioxide | $CO_2$. | Corrosion in water lines and particularly steam and condensate lines. | Aeration. Deaeration. Neutralization with alkalies. Filming and neutralizing amines. |

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| pH | Hydrogen ion concentration defined as the logarithm of the reciprocal of the hydrogen ion concentration. | pH varies according to acidic or alkaline solids in water. Most natural waters have a pH of 6.0 to 8.0. | pH can be increased by alkalies and decreased by acids. |
| Sulfate | $(SO_4)^{--}$ | Adds to solids content of water but in itself is not usually significant. Combines with calcium to form calcium sulfate scale. | Demineralization. Distillation. |
| Chloride | $Cl^-$ | Adds to solids content and increases corrosive character of water. | Demineralization. Distillation. |
| Nitrate | $(NO_3)$ | Adds to solids content, but is not usually significant industrially. High concentrations cause methemoglobinemia in infants. Useful for control of boiler metal embrittlement. | Demineralization. Distillation. |
| Fluoride | $F^-$ | Cause of mottled enamel in teeth. Also used for control of dental decay. Not usually significant industrially. | Adsorption with magnesium hydroxide, calcium phosphate, or bone black. Alum coagulation. |
| Silica | $SiO_2$ | Scale in boilers and cooling water systems. Insoluble turbine blade deposits due to silica vaporization. | Hot process removal with magnesium salts. Adsorption by highly basic anion exchange resins, in conjunction with demineralization. Distillation. |
| Iron | $Fe^{--}$ (ferrous)<br>$Fe^{---}$ (ferric) | Discolors water on precipitation. Source of deposits in water lines, boilers, etc. Interferes with dyeing, tanning, paper mfr., etc. | Aeration. Coagulation and filtration. Lime softening. Cation exchange. Contact filtration. Surface active agents for iron retention. |
| Manganese | $Mn^{--}$ | Same as iron. | Same as iron. |

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| Oil | Expressed as oil or ether extractible matter. | Scale, sludge and foaming in boilers. Impedes heat exchange. Undesirable in most processes. | Baffle separators. Strainers Coagulation and filtration. Diatomaceous earth filtration. |
| Oxygen | $O_2$ | Corrosion of water lines, heat exchange equipment, boilers, return lines, etc. | Deaeration, sodium sulfite. Corrosion inhibitors. |
| Hydrogen Sulfide | $H_2S$ | Cause of "rotten egg" odor. Corrosion. | Aeration. Chlorination. Highly basic anion exchange. |
| Amonnia | $NH_3$ | Corrosion of copper and zinc alloys by formation of complex soluble ion. | Cation exchange with hydrogen zeolite. Chlorination. Deaeration. |
| Conductivity | Expressed as micromhos, specific conductance. | Conductivity is the result of ionizable solids in solution. High conductivity can increase the corrosive characteristics of a water. | Any process which decreases dissolved solids content will decrease conductivity. Examples are demineralization, lime softening. |
| Dissolved Solids | None | "Dissolved solids" is measure of total amount of dissolved matter, determined by evaporation. High concentrations of dissolved solids are objectionable because of process interference and as a cause of foaming in boilers. | Various softening process, such as lime softening and cation exchange by hydrogen zeolite, will reduce dissolved solids. Demineralization. Distillation. |
| Suspended Solids | None | "Suspended solids" is the measure of undissolved matter, determined gravimetrically. Suspended solids plug lines, cause deposits in heat exchange equipment, boilers, etc. | Subsidence. Filtration, usually preceded by coagulation and settling. |

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| Total Solids | None | "Total solids" is the sum of dissolved and suspended solids, determined gravimetrically. | See "Dissolved Solids" and "Suspended Solids" |

Dept of Civil Engineering Tng
Sheppard AFB, Texas

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# LABORATORY SAFETY

## OBJECTIVE

The purpose of this workbook is to aid you gain a better understanding of laboratory safety.

## PROCEDURE

Complete the following statements by filling in the blank spaces with the proper word(s). Reference: 563X0 Career Ladder Laboratory Manual, page IV-Laboratory Safety Rules.

1. ____________ will always be worn while working in the laboratory.
2. Remove _______________ before handling chemicals.
3. Keep work area ____________ at all times.
4. Do not use ______________ or __________ glassware.
5. Do not use chemicals or reagents which are not properly __________.
6. If chemicals are spilled on you, ____________ immediately with water.
7. Smell chemicals ______________.
8. Do not _______________ chemicals.
9. Always add chemicals to _______; never add __________ to chemicals.
10. Never mix chemicals at ___________.
11. Do not heat ____________ containers.
12. Do not engage in ____________.

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h. Label sample giving the following information:

    (1) Name of collector

    (2) Date of collection

    (3) Duty phone

    (4) Sampling point

    (5) Type of analysis needed

2. Collect and label a wastewater sample which could be used to test for solids.

    a. Obtain a clean widemouth container from lab.

    b. Go to sampling point designated by the instructor.

    c. Using sampling equipment provided, collect a representative wastewater sample.

    d. Label sample giving the following information:

        (1) Name of collector

        (2) Date of collection

        (3) Duty phone

        (4) Sampling point

        (5) Type of analysis needed

205

## DETERMINING TYPES OF HARDNESS

### OBJECTIVE

The purpose of this workbook is to aid you in understanding the types of hardness in water.

### PROCEDURES

Use the rules and charts to solve the following problems when you need them. Fill in the blanks provided after you have determined whether the water contains temporary or permanent hardness, or both kinds. When both kinds of hardness are present, determine the amount of each kind. Assume we are working with raw lake water.

### RULE NUMBER ONE

When "H" (total hardness) is greater than "M" (total alkalinity), both temporary and permanent hardness is present. The amount of temporary hardness will be the same as "M" and the amount of permanent hardness will be equal to the difference in "H" and "M".

### RULE NUMBER TWO

When "M" alkalinity equals or exceeds the "H," all "H" is temporary and there is no permanent hardness.

### CHART

Ca-H = Calcium Hardness
Mg-H = Magnesium Hardness
H = Total Hardness
P = Phenolphthalein Alkalinity
M = Total Alkalinity

PROBLEMS

1. When "H" is 125 and "M" is 125 ________________________
2. When "M" is 124 and "H" is 100 ________________________
3. When "H" is 150 and "M" is 125 ________________________
4. When Ca - "H" is 60, "H" is 90, and "M" is 90 ______________
5. When "M" is 120, Ca - "H" is 80, and "H" is 120 ____________
6. When Ca - "H" is 40, "H" is 140, and "M" is 120 ____________
7. When "P" is 30, "M" is 150, Ca - H is 50, and "H" is 150 ______
8. When Ca - "H" is 60, "H" is 150, "P" is 40 and "M" is 175 _____
9. When "P" is 20, "M" is 40, Ca - "H" is 30 and "H" is 60 _______
10. When Ca "H" is 30, Mg - "H" is 20, "P" is 40 and "M" is 60____
11. When "P" is 30, "M" 90, Ca - "H" is 40, and Mg - "H" is 50_____
12. When Ca - "H" is 40, Mg - "H" is 20, "P" is 40 and "M" is 60____

## COMPOUNDS CAUSING HARDNESS AND ALKALINITY

List the following compounds in the correct column in the table below. NaOH, KOH, $CaCO_3$ $CaSO_4$, $Na2CO_3$, $Ca(HCO_3)_2$ $CaC1_2$, $MgCO_3$, $NaHCO_3$, $MgSO_4$, $MgC1_2$, $Mg(HCO_3)_2$

| Compounds Causing Hardness Alone | Compounds Causing Both Hardness and Alkalinity | Compounds Causing Alkalinity Alone |
|---|---|---|
| | | |

## PROBLEMS ON ALKALINITY

### OBJECTIVE

The purpose of this workbook is to aid you in working problems relating to "P" and "M" alkalinity.

### PROCEDURE

The following chart gives the relationship between "P" and "M" alkalinity. Using the chart, solve problems 1 through 10 and list your answers on the blank lines. You are to determine the amount of alkalinity (OH, $CO_3$ and $HCO_3$) and concentration present.

| CONDITIONS OF ALKALINITY | HYDRATE OH | CARBONATE $CO_3$ | BICARBONATE $HCO_3$ |
|---|---|---|---|
| P = O | O | O | M |
| P = M | M | O | O |
| P = 1/2M | O | M | O |
| P = > 1/2M | 2P-M | 2(M-P) | O |
| P = < 1/2M | O | 2P | M-2P |

1. When the total alkalinity (M) is 40 ppm ______________________,
and "P" alkalinity is also 40 ppm ______________________.

2. When the total alkalinity (M) is 60 ppm ______________________,
and "P" alkalinity is 30 ppm ______________________.

3. When the total alkalinity (M) is 25 ppm ______________________,
and "P" alkalinity (0) zero ______________________.

4. When the total alkalinity (M) is 40 ppm ______________________,
and "P" alkalinity is 10 ppm ______________________.

5. When the total alkalinity (M) is 50 ppm ______________________,
and "P" alkalinity is 30 ppm ______________________.

6. When the total alkalinity (M) is 35 ppm____________________,

and "P" alkalinity is (0) zero____________________.

7. When the total alkalinity (M) is 50 ppm, ____________________,

and "P" alkalinity is 50 ppm____________________.

8. When the total alkalinity (M) is 70 ppm, ____________________,

and "P" alkalinity is 35 ppm____________________.

9. When the total alkalinity (M) is 60 ppm____________________,

and "P" alkalinity is 40 ppm____________________.

10. When the total alkalinity (M) is 60 ppm____________________,

and "P" alkalinity is 20 ppm____________________.

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Department of Civil Engineering Training

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# 563X0 CAREER LADDER
# LABORATORY MANUAL
# ALL COURSES

February 1972

SHEPPARD AIR FORCE BASE

Designed For ATC Course Use

DO NOT USE ON THE JOB

# PREFACE

This manual has been written for use in the 563X0, Water and Waste Processing Courses. Its purpose is to aid you in acquiring the basic knowledges and skills needed to perform the laboratory tests used in water and waste analyses.

The tests and procedures used in this manual have been selected from several sources and modified to meet classroom conditions.

For specific instructions on field testing, you should refer to Analysis of Water and Sewage, by Theroux, Eldridge, and Mullman; Standard Methods of Water Analysis, American Public Health Association; manufacturer's instructions, or other authorized laboratory manuals.

You will not perform every test listed in this laboratory manual. You will do only those tests that fall within the scope and proficiency level of the course you are attending.

## TABLE OF CONTENTS

PAGE

Preface i
Table of Contents ii
General Laboratory Procedures iii
Laboratory Safety Rules iv
Collecting and Labeling Water and Wastewater Samples v

TEST

Acidity 1
Alkalinity 4
Amines (Neutralizing) 7
Bio-chemical oxygen demand 8
Carbon Dioxide (Free) 10
Chloride 13
Chlorine Residual (Total) 15
Chromates 17
Color 18
Fluoride 20
Hardness (EDTA) 22
Hardness (Soap Titration) 24
Iron (Dissolved) 26
Jar Test 28
Oxygen (Dissolved) 31
pH (Electric meter) 33
pH (Taylor Water Analyzer) 36
Phosphate 38
Relative Stability 41
Silica 43
Solids (Dissolved 45
Solids (Settleable) 46
Solids (Suspended) 47
Solids (Total) 49
Solids (Volatile) 51
Specific Conductance 53
Sulfate 55
Sulfite 57
Tannin 58
Taste and Odor 59
Temperature 62
Titration (Volumetric), Procedures for 64
Turbidity 68

## GENERAL LABORATORY PROCEDURES

The following procedures are applicable to all laboratory tests:

1. Observe all safety rules applicable to the test (see Laboratory Safety Rules).

2. Select chemicals and equipment needed for the test.

3. Clean all equipment before using. NOTE: Do not use transfer pipettes for more than one reagent unless cleaned before each use.

4. Collect sample as needed for test.

5. Perform the test.

6. Compute results.

7. Record results. NOTE: Results are not correct unless recorded in proper units.

8. Clean equipment and work area.

9. Store equipment as directed.

# LABORATORY SAFETY RULES

The following safety rules must be observed when working in the laboratory or during field testing:

1. Wear and use necessary safety equipment. NOTE: Aprons will always be worn while working in the laboratory.
2. Remove jewelry before handling chemicals.
3. NEVER mix chemicals at random.
4. Smell chemicals slowly.
5. Keep work area clean at all times.
6. Do NOT use chemicals or reagents which are not properly identified.
7. If chemicals are spilled on you, wash immediately with water. NOTE: If hands feel slick or burn, wash them.
8. Do NOT use chipped or cracked glassware.
9. Do NOT heat closed containers.
10. Do NOT engage in horseplay.
11. Always add chemicals to water; NEVER add water to chemicals.
12. Do NOT taste chemicals.

## COLLECTING AND LABELING WATER AND WASTEWATER SAMPLES

The following questions and procedures will assist you in learning the process of collecting and labeling water and wastewater samples.

### QUESTIONS

1. What is the purpose of sampling?

2. Why should samples be labeled?

3. What are grab samples?

4. What is a composite sample?

5. What areas of a lake, stream, or spring should be avoided when collecting water samples?

6. List the steps required to collect a water sample from a lake.

### PROCEDURES

1. Collect water sample for pH analysis. Sample will be taken from an area designated by the instructor.

    a. Obtain a clear 300 Ml bottle from the lab.

    b. Go to sampling point designated by the instructor and throughly flush the sampling line.

▼

c. Rinse sample bottle thoroughly with water to be tested.

d. Adjust sampling line to fill container.

e. Using a slow, steady flow, fill sample bottle to overflowing.

f. Turn off tap and immediately cap sample bottle.

g. Lable sample giving the following information:

    (1) Name of collector
    (2) Date of collection
    (3) Sampling point
    (4) Source of water
    (5) Temperature of sample
    (6) Type of analysis needed

h. Take sample to lab for testing and analysis.

2. Collect and label a wastewater sample for settleable solids test.

    a. Obtain a clean widemouth container (1000 Ml beaker) from lab.

    b. Go to sewage trainer and collect an effluent sample.

    c. Label sample, giving the following information.

        (1) Name of collector
        (2) Phone number
        (3) Date of collection
        (4) Place sample taken
        (5) Temperature of sample
        (6) Type of analysis needed

    d. Take sample to lab for tests and analysis.

# ACIDITY TEST

**Purpose of Test:** To determine the amount of free mineral acidity (FMA) and total acidity present in a sample.

**Method of Testing:** Volumetric titration using color indicators to determine the end point.

**Principles of Test:**

1. Free mineral acids in a water solution will cause a pH of 4.5 or below.
2. In the absence of FMAs or after their removal, the weak acid will cause a pH above 4.5 and below 8.3.
3. Using an alkaline reagent, the FMAs are neutralized; and methyl orange is used as the end point indicator. The weak acids are then neutralized, using phenolphthalein as the end point indicator.
4. The basic reactions are: $NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + H_2O$ (FMA neutralization).

   $NaOH + H_2CO_3 \longrightarrow NaHCO_3 + H_2O$ (weak acid neutralization)

**Equipment:**

1. Burette
2. Graduated cylinder
3. Erlenmeyer flask

**Reagents:**

1. 0.02N sodium hydroxide
2. Methyl orange indicator
3. Phenolphthalein indicator
4. 0.1N sodium thiosulfate

**Procedure:**

**A. Free mineral acidity**

1. Pour 50 ml. of the sample in an Erlenmeyer flask.

2. Add one drop of sodium thiosulfate ($Na_2S_2O_3$) to the sample.

3. Add three drops of methyl orange indicator. If the sample turns straw yellow there is no acid (FMA) in the sample. If the sample turns pink there is FMA. Continue the test.

4. For comparison purposes, measure 50 ml. of distilled water into another Erlenmeyer flask and add 3 drops of methyl orange. This is a straw yellow color. This straw yellow is the endpoint of the coming titration. Keep this flask and water for comparison.

5. Fill a burette with .02N NaOH.

6. If the sample from step 4 is even slightly orange or pink, titrate with the 02N NaOH while stirring. Titrate over a sheet of white paper until endpoint color of straw yellow is reached.

7. Read the burette and multiply by 20 to give the ppm of FMA. Save this sample for the total acidity test which follows:

   FMA = 20 x ml. of NaOH titrate

8. Record your ppm below:

   Special Sample FMA = ______________________ ppm.

9. Continue testing this sample below. Do not refill the burette or toss the sample away.

**B. Total Acidity**

1. Add 3 drops of phenolphthalein to the water sample used above.

   NOTE: If a pink or orange appears, the total acidity and the FMA are the same.

2. If no color change appears, titrate further with the NaOH to a pink or an orange color.

3. Read the burette and multiply by 20.

4. Record the total acidity.

Special Sample total acidity = ______________________ ppm.

NOTE: To find carbonic acid content subtract FMA from total acidity.

# ALKALINITY

**Purpose of Test:** To determine the amount of alkaline compounds in a sample, the acid neutralizing capacity, and the type of alkaline anions present.

**Method of Testing:** Volumetric titration using pH color indicators to determine end point.

**Principles of Test:**

1. The anions which normally cause alkalinity in water are hydroxides (OH-), carbonates ($CO_3$-) and bicarbonates ($HCO_3$-).
2. Due to the ionization constants of the $CO_2$ compounds the following conditions exist:
   a. Where significant hydroxides (OH-) exist, all $CO_2$ would be in the carbonate ($CO_3$-) form and no bicarbonates ($HCO_3$-) would be present.

   b. In the absence of hydroxides (OH-) and with a pH above 8.3, the $CO_2$ would be in the form of $CO_3$.

   c. At a pH of 8.3 all $CO_2$ is $HCO_3$.

   d. Between pH of 8.3 and 4.8, the $CO_2$ is in the form of $HCO_3$ and $H_2CO_3$. (Carbonic acid)

   e. At or below a pH 4.8, all $CO_2$ is in the form of carbonic acid ($H_2CO_3$).
3. The alkalinity due to (OH-) and 1/2 of the alkalinity due to carbonates is neutralized with 0.02N sulfuric acid to a pH of 8.3. This amount of alkalinity is computed and reported as "P" alkalinity.
4. The remaining 1/2 carbonate alkalinity and the total bicarbonate alkalinity is neutralized to a pH of 4.8, and the total amount of acid is used to compute the alkalinity (total alkalinity).

5. The (OH-) ($HCO_3$-) alkalinity is computed, using a chart based on the above stated conditions and their relationship to "P" and "M" alkalinity.

Equipment:

1. Burette
2. Graduated cylinder
3. Erlenmeyer flask or casserole

Reagents:

1. 0.02N sulfuric acid
2. Phenolphthalein indicator
3. Bromocresol green - methyl red
4. 0.1N sodium thiosulfate

Procedure:

1. Measure 50 ml. of the sample into a graduated cylinder and pour it into an Erlenmeyer flask.

2. Add 1 drop of 0.1N sodium thiosulfate to remove residual chlorine to prevent bleaching of the indicators.

3. Add 3 drops of phenolphthalein indicator.

    a. If the sample turns pink "P" alkalinity is present. Proceed to step 4.

    b. If the sample turns clear, no "P" alkalinity is present. Record ml. acid for "P" - 0 and proceed to step 6.

4. Titrate with 0.02N sulfuric acid until pink color fades away.

5. Record ml. acid for "P" = ________________________.

6. Add 3 drops bromocresol green - methyl red indicator.

a. If the sample turns pink or light pink with a bluish tint, "M" alkalinity is the same as "P" alkalinity. Record ml. acid for "M" = ________________. Proceed to step 8.

b. If the sample does not turn pink or pink with a blue tint proceed to step 7.

7. Continue the titration until the sample turns pink or light pink with a bluish tint. Record ml. acid for "M" = ______________.

8. Compute and record "P" and "M" alkalinity as follows:

The ml. acid for "P" x 20 = ___________ PPM "P" alkalinity as $CaCO_3$
The ml. acid for "M" x 20 = ___________ PPM "M" alkalinity as $CaCO_3$

9. Using "P" and "M" determined and relationship table below, compute and record (OH-), ($CO_3$-) alkalinity of sample.

| CONDITIONS OF ALKALINITY | HYDRATE (OH-) | CARBONATE ($CO_3$) | BICARBONATE ($HCO_3$-) |
|---|---|---|---|
| P = 0 | 0 | 0 | M |
| P = M | M | 0 | 0 |
| P = 1/2M | 0 | 0 | 0 |
| P = is greater than 1/2M | 2P-M | 2(M-P) | 0 |
| P = is less than 1/2M | 0 | 2P | M-2P |

a. (OH-) alkalinity = _______________ PPM as $CaCO_3$

b. ($CO_3$-) alkalinity = ______________PPM as $CaCO_3$

c. ($HCO_3$-) alkalinity = ____________ PPM as $CaCO_3$

## AMINES NEUTRALIZING

**Purpose of Test:** To determine if adequate amines are present in the boiler water.

**Method of Testing:** Adequacy of amine treatment is determined by measuring pH and not in terms of amines.

**Principle of Test:** When pH of condensate is 7.0, amine treatment is sufficient.

For equipment and procedures refer to test for pH.

# BIO-CHEMICAL OXYGEN DEMAND

Purpose of Test: To determine the oxygen required by the microscopic organisms in the sample to oxidize the organic matter in a sample.

Method of Testing: Analysis before and after incubation to determine the amount of oxygen present.

Principles of Test:

1. Aerobic organisms will decompose organic material in sewage if adequate dissolved oxygen is present. The oxygen used will be proportaional to the material decomposed.

2. Adequate oxygen is insured by diluting the sample with distilled water saturated with oxygen. The amount of dilution depends on the strength of the sewage sample as follows:

   a. Raw sewage - 2% 20 ml. per 1000 ml. total dilution
   b. Settled sewage - 3% 30 ml. per 1000 ml. total dilution
   c. Plant effluent - 5% 50 ml. per 1000 ml. total dilution
   d. Stream sample - 25 to 100% depending on condition of stream - 250 ml. per 1000 ml. total dilution

3. The sample is incubated at 20°C. to provide uniform conditions for bacterial growth and give uniform results for reporting.

4. The incubation covers 5 days, and the results reported imply that it is the 5th day BOD unless otherwise stated. The 5 day BOD actually represents 68% of the total BOD.

Equipment:

1. Two BOD bottles
2. Siphon tube
3. Plunger type mixing rod
4. Graduate cylinder (100 ml.)
5. Erlenmeyer flask
6. Three pipetts
7. Burette
8. Incubator at 20°C.
9. Graduated cylinder (1000 ml.)

**Reagents**

1. Dilution water
2. Manganous sulfate
3. Alkaline potassium iodide oxide
4. Concentrated sulfuric acid
5. 0.025 sodium thiosulfate
6. Starch solution

**Procedure:**

1. Siphon 400 ml. of dilution water into 1000 ml. graduated cylinder.
2. Add sample according to strength of sample (see principle #2).
3. Fill the cylinder to the 1000 ml. mark with additional dilution water and mix gently with mixing rod.
4. Use siphon to fill 2 BOD bottles with diluted sample.
5. Perform a D.O. test on one bottle and record results as follows: Unincubated sample = ________________ PPM D.O.
6. Stopper the second bottle and place it in the incubator for 5 days. NOTE: Keep water in the lip of the stoppered bottle.
7. After the 5 day incubation run a D.O. test on the second bottle and record results as follows: Incubated sample = ________ PPM D.O.
8. Compute and record BOD of original sample as follows:

$$\frac{\text{D.O. before incubation - D.O. after incubation X 1000}}{\text{ml. of sample}} =$$

____________________ PPM BOD of sample

## FREE CARBON DIOXIDE

Purpose of Test: To determine the amount of free carbon dioxide which can be released from the carbonic acid in a water sample.

Method of Testing: Volumetric titration using pH color indicators to determine end-point.

Principles of Test:

1. Due to the ionization constants of the compounds containing carbon dioxide in water, the following conditions exist:

   a. With a pH above 8.3, all carbon dioxide in solution will be in the carbonate or bicarbonate form and no carbonic acid will be present.
   b. At a pH of 8.3, all carbon dioxide will be in the bicarbonate form.
   c. Between a pH of 8.3 and 4.5, the carbon dioxide will be in the bicarbonate form and carbonic acid form.
   d. Below or at a pH of 4.5, all of the carbon dioxide will be carbonic acid; but this condition can exist only if Free Mineral Acids are present. In this case a FMA and total acidity test would have to be performed.

2. In this test, in the absence of FMA, the carbonic acid is neutralized to the bicarbonate equivalent pH of 8.3 with a standard alkaline reagent as follows:

   a. $H_2CO_3 + NaOH \longrightarrow NaHCO_3 = H_2O$

   b. $H_2CO_3 + Na_2CO_3 \longrightarrow 2NaHCO_3$

Equipment:

1. Rubber tube
2. 50 ml. graduated cylinder
   NOTE: The use of a rubber tube to obtain the sample and use of a small mouth container is necessary to prevent loss of or absorption of carbon dioxide

3. Stirring rod
4. Burette

Reagents:

1. Phenolphthalein indicator
2. Methyl orange indicator
3. 0.0454N sodium carbonate or 0.0227N sodium hydroxide
   NOTE: Reagent must be free of $CO_2$

Procedure:

1. Add 3 drops of phenolphthalein indicator to approximately 15-20 ml. of sample.
   a. If a pink color develops, no free carbon dioxide is present. Record results as PPM Free Carbon Dioxide
   b. If sample is colorless proceed to Step 2.
2. Add 3 drops of methyl orange indicator.
   a. If a pink color develops, FMA are present and this test is not applicable. Record results as FMA present
   b. If the sample turns yellow continue to step 3
3. Collect 50 ml. of sample by means of a rubber tube discharging at the bottom of a 50 ml. graduated cylinder. Allow the sample to overflow the cylinder and withdraw the tube while sample is flowing. Remove excess sample with a pipette or by flicking the cylinder.
4. Add 3 drops of phenolphthalein.
5. Titrate with a standard sodium hydroxide or sodium carbonate (N/50) stirring gently until a definite pink color persists for 30 seconds. This is the end point.
6. Read burette and record ml. of reagent used = _________________.

7. Compute and record results as follows:

   a. The ml. of reagent X 22.7 = ______________ PPM $CO_2$ as $CaCO_3$

   b. The ml. of reagent X 20 = ____________ PPM $CO_2$ as $CO_2$

NOTE: If different normalities or amounts of sample are used, the results may be computed as follows:

a. Where sodium hydroxide is used

$$\frac{\text{ml.} \times N \times 44000}{\text{ml. sample}} = \text{PPM } CO_2 \text{ as } CO_2$$

$$\frac{\text{ml.} \times N \times 500000}{\text{ml. sample}} = \text{PPM } CO_2 \text{ as } CACO_3$$

b. Where sodium carbonate is used

$$\frac{\text{ml.} \times N \times 22000}{\text{ml. sample}} = \text{PPM } CO_2 \text{ as } CO_2$$

$$\frac{\text{ml.} \times N \times 25000}{\text{ml. sample}} = \text{PPM } CO_2 \text{ as } CaCO_3$$

# CHLORIDE

Purpose of Test: To determine the amount of chlorides in the water.

Method of Testing: Selective precipitation by volumetric titration using the formation of insoluble silver chromate as end point indicator.

Principles of Test:

1. At a pH between 7 and 10 silver nitrate will precipitate the chlorides as silver chloride.
2. Once the chlorides are precipitated, a slight excess of silver nitrate will react with potassium chromate (yellow indicator) to precipitate silver chromate which is red.
3. Due to the presence of the white silver chloride precipitate, the yellow potassium chromate and the red silver chromate precipitate. The end point color is determined by using a distilled water blank.

Equipment:

1. Graduated cylinder
2. 2 Casseroles
3. Burette
4. Stirring rod

Reagents:

1. Phenolphthalein indicator
2. 0.0141N silver nitrate
   NOTE: Silver nitrate should be standardized daily and calculations made accordingly.
3. 0.1N sulfuric acid
4. 0.1N sodium hydroxide
5. Potassium chromate indicator solution

Procedure:

1. Pour 50 ml. of distilled water in a casserole.
2. Add 1 ml. of potassium chromate indicator.
3. Titrate with silver nitrate until a reddish pink color develops. Record ml. of reagent for blank ______________. Save this blank for determining the end point of sample titrated.

4. Pour 50 ml. of sample into a second casserole.
5. Add 2 drops of phenolphthalein and adjust pH as follows:

    a. If sample turns pink add 0.1N sulfuric acid until the pink color fades away and continue to step 6.
    b. If sample turns clear add 0.1N sodium hydroxide, drop at a time, until a slight pink color develops and continue to step 6.

6. Add 1 ml. of potassium chromate indicator.
7. Titrate with silver nitrate reagent until color of blank is reached.
8. Compute results as follows:

$$\text{PPM chloride} = \frac{\text{ml. reagent for a sample - ml. reagent for blank X Normality of silver nitrate X 35,450}}{\text{ml. of sample}}$$

# TOTAL CHLORINE RESIDUAL

Purpose of Test: To determine the "Total Available Chlorine" in a water sample.

Method of Testing: Visual color comparison

Principles of Test:

1. Orthotolidine in the presence of hypo-chlorous acid (free available chlorine) or chloro-amines (combined available chlorine) will develop a yellow color.

2. The intensity of the color will be proportional to the amount of these forms of chlorine present.

3. The color developed is compared to the standard colors on the chlorine residual standard color disc.

Equipment:

1. Hellige color comparator kit which includes:
    a. Color comparator (body)
    b. Chlorine disc
    c. Two glass tubes

2. Small beaker for sample

Reagent:

Orthotolidine in bottle with 0.5 ml. dropper

Procedure:

1. Place chlorine residual disc in the comparator.
2. Add 0.5 ml. of orthotolidine to one tube.
3. Fill the second tube to the 10 ml. mark with sample to be tested.
4. Transfer the sample from the second tube to the first tube. (This allows mixing of sample with the orthotolidine)
5. Place the tube with sample and orthotolidine in comparator so that it can be viewed through the center of the disc.

6. Fill the second tube with sample to the 10 ml. mark and place it in the second compartment of the comparator.

7. Hold the comparator toward the light and rotate the disc until color of sample is matched with a color on the disc.

8. Read the number shown in the opening of the comparator. (This is the chlorine residual in PPM).

9. Record your results:

Total available residual ____________________ PPM.

## CHROMATES

**Purpose of Test:** To determine the chromate concentration in chromate treated cooling water samples.

**Method of Testing:** Visual color comparison.

**Principles of Test:**

1. Chromates in the concentration used for treatment of cooling water cause a yellow color proportionate to the chromate concentration.

2. The color produced is compared to that of chromate color standards.

**Equipment:**

1. Hellige color comparator
2. Two comparator tubes
3. Chromate color standard disc

**Reagents:** None

**Procedure:**

1. Place color disc in the comparator.
2. Fill one tube with sample and place in the comparator so that it will be viewed through the center of the disc.
3. Fill second tube with clear water and place in second compartment of the comparator.
4. Hold comparator toward light and rotate disc until a color match is obtained.
5. Read PPM indicated in open window on face of comparator.
6. Record results:

   Sample No. 1 ____________________ PPM chromates.

# COLOR (HELLIGE)

**Purpose of Test:** To determine the intensity of color in a water sample.

**Method of Testing:** Visual color comparison with standard color disc.

**Principles of Test:**

1. Most of the true color in natural water supplies are cause by dissolved tannin-like organic material from decaying vegetation which in dilute concentration gives a yellow color to water.

2. Suspended matter and precipitated iron or manganese may give the water an apparent color which must be removed by centrifuge or filtration using a nonabsorbent filter aid.

3. The color of a turbidity free sample is compared to the color of platinum-cobalt standard color disc and the color reported in standard color units.

**Equipment:**

1. Hellige aqua-tester
2. Two aqua-tester Nessler tubes with plungers
3. Color standard disc

**Reagents:** None

**Procedure:**

1. Fill one of the Nessler tubes with turbidity free sample. NOTE: If turbidity is present and the equipment is not available for centrifuging or filtering, the test may be run but the results are reported as apparent color.
2. Swing open the back cover of the aqua-tester. Insert the tube in the right side holder and let it rest in the circular depression of the platform.

3. Fill the second Nessler tube with water of zero turbidity and color and insert it in the left side of comparator.

4. Remove the light shield with eye piece and insert the color testing disc with the numbered side up. Replace the light shield.

5. Make the color comparison by revolving the disc until a color match is made with one of the standards.

6. Read the results directly from the figure seen in the circular opening on the light shield. If the color of the sample is between two standard colors, estimate the value.

7. Record the results as follows: ____________________ color units.

# FLUORIDE TEST (HELLIGE)

Purpose of Test: To determine the fluoride content of water.

Method of Testing: Visual color comparison

Principles of Test:

1. Fluoride ions in the presence of Zirconium-Alizanin (fluoride reagent) will develop a color proportional to the amount of fluoride ions.

2. The color developed is matched with a standard color on a fluoride standard color disc.

Equipment:

1. Hellige "aqua-tester" complete with:
    a. Fluoride color disc
    b. Two Nessler tubes
    c. Two plungers
    d. Five ml. pipette
    e. Graduated cylinder (100 ml.)
    f. Erlenmeyer flask with stopper

CAUTION: The glassware for the fluoride test is not to be washed with soap or alkaline solution. It should be rinsed with tap, distilled, or sample water. If further cleaning is necessary clean with 1:1 nitric acid.

Reagents: Fluoride reagent

Procedure:

1. Remove the light shield from the comparator and insert the fluoride color disc. Replace the light shield.
2. Add exactly 2.5 ml. of fluoride reagent to the flask and stopper. Note the time.
3. Let sample set for one hour.

4. Fill one Nessler tube to the mark on the tube with sample containing reagent from step 3 and place plunger in tube.

5. Swing open the back cover of the comparator and place on the tube with reagent in the right hand holder. (Right hand to you while facing the eye piece)

6. Fill second Nessler tube with sample without reagent. Stopper the tube and place in the left hand holder.

7. Close the cover and turn on the light.

8. Make color comparison within 5 minutes after the one hour period by revolving the color disc until a color match is made with sample and disc.

9. Read the results from the figure in the circular opening on the light shield.

10. Record results as follows:

Sample No. 1 = ______________ PPM fluoride

## HARDNESS (EDTA)

Purpose of Test: To determine the total amount of hardness as $CaCO_3$ equivalent, and that portion caused by Ca and Mg.

Method of Testing: Volumetric titration with EDTA (versenate) to form complex Ca and Mg compounds and using organic dyes as end point indicators.

Principles of Test:

1. In a buffered solution, using "Total Hardness Buffer," Ca and Mg will cause a "Total Hardness Indicator" dye to give a red color to the solution.

2. EDTA added to solution will form a complex ion with the Ca and Mg and a slight excess will turn the solution blue.

3. In a solution buffered with "Calcium Buffer" the Mg is rendered inactive and the EDTA plus Ca will cause "Calcium Hardness Indicator" dye to turn pink.

4. EDTA added to this solution will form a complex ion with Ca and a slight excess will turn the solution a red-purple color.

Equipment:

1. Burette
2. Casserole
3. Graduated cylinder
4. Pipette
5. Stirring rod
6. Chemical scoop

Reagents:

1. 0.01 molor Standard EDTA Hardness Solution (1 ml. : 1 PPM)
2. Total harness buffer
3. Total hardness indicator
4. Calcium hardness buffer
5. Calcium hardness indicator

Procedure:

1. Measure 50 ml. of sample and transfer to a casserole.
2. Add 0.5 ml. of Total Hardness buffer and stir to mix.
3. Add one chemical scoop of total hardness indicator and stir until dissolved.
4. Titrate with EDTA to a blue color (end point) and record no. ml. of EDTA used. EDTA for total hardness = ______________ ml.
5. Measure an additional 50 ml. of sample and transfer to a clean casserole.
6. Add 5 ml. of calcium buffer solution.
7. Add one chemical scoop of calcium hardness indicator and stir until dissolved.
8. Titrate with EDTA until a red-purple color (end point) is reached and record ml. of EDTA used. EDTA for calcium hardness = ________ ml.
9. Compute PPM Total Hardness, Calcium Hardness and Magnesium Hardness as follows:

   a. The ml. EDTA for Total Hardness X 20 = ____________ PPM Total Hardness as $CaCO_3$.

   b. The ml. EDTA for Calcium Hardness X 20 = _________ PPM Calcium Hardness as $CaCO_3$.

   c. PPM Total Hardness - PPM Calcium Hardness = _______ PPM Magnesium Hardness.

## TOTAL HARDNESS (SOAP TITRATION)

**Purpose of Test:** To determine the total hardness of water.

**Method of Testing:** Titration with soap to the permanent lather end-point.

**Principles of Test:**

1. Hardness in water will react with soap to destroy the lather forming properties of the soap.

2. A standard soap solution is added in 0.5 ml. portions to a selected volume of sample until a permanent lather forms.

3. PPM hardness is computed as follows (ml. soap solution used minus soap factor) X 20 = PPM Hardness as $CaCO_3$.

**Equipment:**

1. Graduated cylinder (50 ml.)
2. Glass stopped bottle (250 ml.) or Erlenmeyer flask
3. Burette

**Reagents:**

Standard soap solution (1 ml. = 20 PPM Hardness and soap factor = 0.5 ml.)

**Procedure:**

1. Add 50 ml. of sample to bottle.

2. Add 0.5 ml. soap solution to bottle and shake.

    a. If a lather forms and remains for 5 minutes no hardness is present.
    b. If no lather forms or forms and disappears in 5 minutes or less, continue to step 3.

3. Add soap solution in 0.5 ml. portions until a lather is present at the end of 5 minutes.

4. Multiply ml. of soap used by 20 to find total hardness.

5. Compute and record results: Hardness = ______________PPM as $CaCO_3$.

# DISSOLVED IRON TEST (PHOTOMETRIC)

Purpose of Test: To determine the dissolved iron content of a water sample.

Method of Testing: Photo electric color comparison using a photo electric meter, (Photometer)to measure transmitted light.

Principles of Test:

1. Phenanthroline reacts with dissolved iron to produce an orange color whose intensity is proportional to the Fe concentration.

2. The intensity of the color produced is measured by measuring the percent of light by the treated sample as compared to the amount transmitted by a treated blank of distilled water.

3. The iron content is determined by comparing the percent transmission for the sample to the percent transmission of standard samples as shown on a prepared chart.

Equipment:

1. Graduated cylinder (25 ml.)
2. Photometer
3. Two glass photometer tubes
4. Percent transmission to PPM iron conversion chart

Reagents:

Phenanthroline (Hatch Ferrovor powder pillows No. 854)

Procedure:

1. Connect photometer to power source and turn switch to a.c.
   NOTE: The unit should warm for 10 minutes before use.

2. Measure 25 ml. of distilled water and pour it into one of the photometer tubes.

3. Measure 25 ml. of sample and pour it into the second photometer tube.

4. Add the contents of one power pillow to each of the tubes. Mix and allow to stand for at least two minutes, not longer than ten.

5. Place the tube containing the distilled water in the "blank" opening of the photometer.

6. Place the tube containing the sample in the sample opening of the photometer.

7. Insert filter No. 490 into the light path.

8. Slide the clear blank into the light path.

9. Adjust the meter to 100 percent transmission.

10. Slide the sample into the light path.

11. Read percent transmission and record.

12. Consult the conversion chart to convert percent transmission to PPM iron.

13. Record results:

Sample No. 1 ______________ PPM Iron.

# JAR TEST

**Purpose of Test:** To determine optimum day to day chemical dosage for coagulation and flocculation of a water supply when experience or a series of similar tests has established that the best coagulant is ferric chloride, the optimum pH is 8.5 to 11, and that soda ash is the best source of alkalinity.

Method of Testing: Trial Treatment.

Principles of Test:

1. When the proper coagulant, optimum pH, and source of alkalinity for a given water are known, the changes in coagulant dosage to meet day to day changes in the water as determined by adding sufficient alkalinity and progressive amounts of coagulant, mixing, and observing the results of different dosages.

2. In this test, soda ash is added to adjust the pH of 6 one liter samples. Then additional soda ash is added to each sample, proportional to the amount of coagulant to be added to prevent depressing the pH when adding the coagulant.

3. Ferric chloride coagulant is added to each of the samples in progressive amounts and mixed.

4. Mixing time and rates are controlled to duplicate the conditions of the plant being used.

5. The optimum chemical dosage is one using the least amount of chemicals which will produce a pinhead size floc that will settle in 30 minutes leaving a turbidity of less than 10 units (observable clear for classroom work).

Equipment:

1. Six one liter beakers
2. Graduated cylinder (1000 ml.)
3. Laboratory stirrer
4. Pipette

Reagents:

1. Phenolphthalein indicator solution
2. Standard ferric chloride solution (10 grams ferric chloride in 1 liter which will be equivalent to 10 PPM dosage when 1 ml. is added to 1 liter of sample)
3. Standard soda ash solution (10 grams per liter as ferric chloride solution)

Procedure:

1. Determine soda ash needed for pH adjustment as follows:
    a. Measure 1 liter of sample and pour it into beaker.
    b. Add 5 drops of phenolphthalein.
    c. Add soda ash solution 1 ml. at a time until sample turns dark pink or red.
    d. Record ml. of soda ash solution used for pH adjustment in chart below. Discard this sample.

2. Add 1 liter of sample to each of the 6 one liter beakers.
3. Adjust pH by adding soda ash solution to each beaker in the amount determined in step 1. Record amount used in chart below.
4. Add additional soda ash solution to sample beakers as follows:

    Beaker #1 - 0.6 ml; #2 - 1.2 ml: #3 - 2.4 ml; #4 - 3.6 ml; #5 - 4.8 ml; #6 - 6 ml.

5. Place beakers under mixer then turn on mixer. Adjust mixer paddles and beaker to maximum turbulence at 80 RPM (Revolutions Per Minute).
6. Add ferric chloride solution as follows:

    Beaker #1 - 0.5 ml; #2 - 1 ml; #3 - 2 ml; #4 - 3 ml; #5 - 4 ml; #6 - 5 ml.

7. Mix at 80 RPM for 2 minutes.
8. Turn mixer control to 20 RPM and mix for 30 minutes.
9. Turn off mixer and allow to settle for 30 minutes.
10. Observe results and record as A (for acceptable) or NA (not acceptable).

11. Review chart to determine acceptable treatment with the least amount of chemicals used.

12. Compute dosages as follows:

a. The ml. ferric chloride X 10 = PPM ferric chloride.

b. The ml. ferric chloride X 10 X 8.34 = lbs ferric chloride per M-gal.

c. Total ml. soda ash X 10 = PPM soda ash.

d. Total ml. soda ash X 10 X 8.34 = soda ash per M-gal.

### TREATMENT DOSAGE CHART

| Sample No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Soda Ash for pH adj (ml.) | | | | | | |
| Soda Ash for $FeCl_3$ | | | | | | |
| Total soda ash | | | | | | |
| The ml. $FeCl_3$ | | | | | | |
| Total Chemical | | | | | | |

# DISSOLVED OXYGEN (STD METHODS)

Purpose of Test: To determine the dissolved oxygen in a water or sewage sample.

Mtehod of Testing: Volumetric Titration.

Principles of Test:

1. Manganous sulfate reacts in an alkaline solution to form manganous hydroxide (white precipitate if oxygen is absent).
2. Oxygen will react with the manganous hydroxide to form a brown precipitate of manganic basic oxide.
3. Upon the addition of sulfuric acid, the brown precipitate dissolves forming manganic sulfate.
4. The manganic sulfate immediately reacts with the potassium iodide to form potassium sulfate and free iodine. The iodine released is proportional to the D.O. in the sample.
5. The iodine is titrated with sodium thiosulfate as the reagent and starch as the end point indicator.

Equipment:

1. BOD bottle (300 ml.)
2. Three pipettes
3. Burette
4. Erlenmeyer flask
5. Suction bulb

Reagents:

1. Manganous sulfate
2. Alkaline potassium iodide oxide
3. Concentrated sulfuric acid
4. 0.025N sodium thiosulfate
5. Starch solution

Procedure:

1. Fill BOD bottle with sample. Observe rules for taking sample for dissolved gases.
2. Add 2 ml. manganous sulfate. NOTE: Add each reagent with a clean pipette. Submerge tip of pipette to deliver reagent, but not deep enough to allow sample to enter pipette.
3. Add 2 ml. of potassium iodide.
4. Stopper the bottle, pour off excess solution, and mix contents by shaking the bottle. Allow precipitate to settle half way. Shake again and allow precipitate to settle half way again.
5. Add 2 ml. sulfuric acid. CAUTION: Acid is dangerous. Handle carefully.
6. Stopper bottle, pour off excess, shake and allow to set for 5 minutes.
7. Transfer 100 ml. of the treated sample to an Erlenmeyer flask. NOTE: If extreme accuracy is required use 101.5 ml. See Standard Methods of Water Analysis.
8. Titrate with 0.025N sodium thiosulfate until yellow color becomes light yellow.
9. Add 2 ml. starch solution.
10. Continue titration to the first disappearance of the blue color.
11. Read burette and record: Sodium thiosulfate used = ________ml.
12. Compute PPM D.O. as follows:
    ml. sodium thiosulfate times 20 = PPM D.O.
13. Record results: as ________________PPM D.O.

## pH (ELECTRIC METER)

Purpose of Test: To measure the free hydrogen ion concentration (pH) of a water sample as a measurement of its degree of acidity or alkalinity.

Method of Testing: Electric pH Meter

Principles of Test:

1. Measurement of pH is accomplished by determining the potential developed by an electrical cell.

2. The anode half cell or reference electrode consists of a glass tube containing mercury mercurous chloride immersed in a saturated KC1 solution. The tube has a porous tip to allow a liquid junction between the half cell and the sample. The half cell has a constant potential.

3. The cathode half cell electrode consists of a glass electrode which is sensitive to the hydrogen ion in the sample. The potential of the half cell varies with the hydrogen ion concentration of the solution.

4. Since the potential of the reference electrode is constant, the potential of the cell depends on the hydrogen ion concentration of the sample.

5. The black scale on the meter is calibrated to read the pH, negative log of the hydrogen ion concentration, equivalent to the electrical potential produced by the cell.

6. Due to the change of sensitivity of the meter at different pHs, the unit must be standardized with a buffered solution of a known pH, before testing the sample.

Equipment:

1. Zeromatic pH meter
2. 50 ml. beaker (for buffer)
3. 150 ml. beaker (for distilled water rinse and sample)

Reagents:

1. Saturated KC1 solution
2. pH buffer (near pH of estimated sample)

Procedure:

a. Preparing the meter

1. Remove the cover.
2. Depress the manual and standby buttons on the meter.
CAUTION: Never remove the glass electrodes from water with the "READ" button depressed.
3. Slide the rubber tube covering the small hole on the reference electrode down to uncover the hole.
4. Remove the rubber boot from the reference electrode.
CAUTION: Both electrodes must be handled carefully and kept clean since they are very sensitive to scratches and the contaminating ions.
5. Check the level of KC1 solution in the reference electrode. Add sufficient KC1 solution to cover the bright mercury if needed.
6. Lower electrodes approximately 2 inches into distilled water and allow to soak for several hours.

b. Standardizing the meter

1. Pour approximately 1 inch of pH7 buffer in the 50 ml. beaker.
2. Submerge electrodes in this buffer.
CAUTION: Do not allow probes to come in contact with the bottom of beaker.
3. Set temperature knob to room temperature.
4. Depress "READ" button.
5. Turn "Standardize" knob until the meter indicates pH7 on the black scale of the buffer.
NOTE: The indicator may tend to drift. Allow time for it to stabilize before reading.
6. Depress standby button.

c. Determining pH of sample

1. Using 150 ml. beaker and distilled water rinse the electrodes three times using fresh distilled water each time.
2. Rinse beaker and electrodes with sample and discard this water.
3. Refill beaker with sample and submerge probes approximately one inch.
4. Obtain temperature of sample and set temperature knob on meter to that sample.
5. Depress "READ" button and allow indicator to stabilize.
6. Read the meter and record to the nearest 0.1 pH.
   Sample pH = ____________________.
7. Push "Standby" button down.
8. If equipment is to be left in the standby position, rinse electrodes with distilled water and leave them submerged in distilled water.

d. Storing meter

1. Unplug the meter.
2. Remove electrodes from water, and rinse with distilled water.
3. Cover the reference electrode fill holes.
4. Replace boot on reference electrode.
5. Cover the meter.

## pH (TAYLOR WATER ANALYZER)

Purpose of Test: To determine the hydrogen ion concentration of a water sample as a measure of its degree of acidity or alkalinity.

Method of Testing: Visual color comparison using the Taylor Water Analyzer.

Principles of Test:

1. Certain organic dyes, pH indicators, give a specific color to a water sample at or below a certain pH and change to another color at or above a higher pH. When the pH is between the high and low ranges, the color or shade of color will vary with the pH. The pH range and color produced are specific to the indicator used.

2. The color produced when an indicator is added to the sample is matched to a standard color in a color slide which is specific to the indicator used.

Equipment:

1. Taylor Water Analyzer
2. 3 Nessler tubes - 150 mm
3. Beaker for sample
4. (3) Taylor Water Analyzer slides for the following indicators:
   a. Pehnol Red
   b. Chlorophenol Red
   c. Bromocresol Green

Reagents:

1. Phenol Red indicator
2. Chlorophenol Red indicator
3. Bromocresol Green indicator

Procedure:

1. Fill 2 of the Nessler tubes to the mark on tube with sample.
2. Place these 2 tubes in the outer compartments of the analyzer.
3. Add 3 drops of chlorophenol red indicator to the 3d tube, fill to mark with sample, and mix.
4. Place the 3rd tube in the center compartment of the analyzer.
5. Place the chlorophenol red slide in the analyzer slide track with one of the arrows point to point with the arrow on the analyzer.
6. Move the slide from arrow to arrow until the closest match between the sample and standard is made. With arrows point to point, the center color reflected on the mirror is the sample and the outer colors are the standards.
7. Read the pH as indicated on the slide directly above the standard matched to the sample and proceed as follows:
    a. If the pH is less than 5.8 but greater than 5.2, report this as the pH of the sample. Proceed to step 12.
    b. If the pH is 5.2, proceed to step 8.
    c. If the pH is 6.8, proceed to step 10.
8. Repeat steps 3 thru 8 substituting bromocresol green indicator and slide for chlorophenol red and indicator slide.
9. Make color match and report as follows:
    a. If pH is greater than 3.8 report it as the pH of sample.
    b. If pH is 3.8 report "3.8 or below" as the pH of the sample. Omit steps 10 and 11.
10. Repeat steps 3 thru 8 substituting phenol red indicator and phenol red slide for chlorophenol red indicator slide.
11. Make color match and report as follows:
    a. If pH is below 8.4 report it as the pH of sample.
    b. If pH is 8.4 report pH of sample as "8.4 or above."
12. Record results:
    pH of sample: ____________________

## PHOSPHATE (TAYLOR HIGH PHOSPHATE COMPARATOR)

Purpose of Test: To determine the total dissolved phosphates in a water sample. To determine also the amount which is orthophosphate and the which is polyphosphate.

Method of Testing: Visual color comparison.

Principles of Test:

1. Orthophosphates will react with molybdate reagent to form phosphomolybdic acid.

2. Stannous chloride will react with the acid to form an intensely colored complex compound, molybdenum blue, the intensity of which is proportional to the orthophosphate in the sample.

3. The intensity of the color is matched to standard phosphate colors.

4. Polyphosphates may be converted to orthophosphates by boiling a sample to which acid has been added.

5. Total dissolved phosphates are determined by first converting the polyphosphates in one sample to orthophosphates by boiling and then testing for orthophosphates.

6. Orthophosphates can be determined on a sample without boiling.

7. Polyphosphates are determined by subtracting orthophosphates from polyphosphates.

a. Orthophosphates

Equipment and reagents:

Taylor high phosphate color comparator kit complete with:

1. Color comparator
2. Three comparators

3. Special measuring and mixing tube
4. Rubber stopper
5. Graduated cylinder (10 ml.)
6. High phosphate comparator slide
7. Small bottle with stopper (for making stannous chloride dilution)
8. Small bottle of conc. stannous chloride
9. Molybdate reagent

Procedure:

1. Make dilute stannous chloride solution by adding 0.5 ml. conc. stannous chloride to clean dilute stannous chloride bottle, and filling bottle with distilled water and mixing. Save for step 5.

2. Fill mixing tube to the 5 ml. mark with clear sample water.

3. Add 10 ml. of molybdate reagent to the mixing tube. If measurements are accurate this will fill tube to 15 ml. mark.

4. Insert clean rubber stopper and mix tube contents.

5. Add 2.5 ml. of dilute stannous chloride to mixing tube (to the 17.5 mark) and mix.

6. Fill one of the comparator tubes to the 5 ml. mark with treated sample and place it in the center of the comparator.

7. Fill 2 comparator tubes with untreated sample and place on each side of treated sample in the comparator.

8. Insert high phosphate color standard slide and make color match.

9. Read and record results as orthophosphates as $PO_4$ = ______ PPM.

b. Total Phosphates

Equipment and reagents:

1. Same as for orthophosphates plus
2. Erlenmeyer flask (250 ml.)

3. Bunsen burner and stand or hot plate
4. Phosphate reversion acid
5. Phosphate reversion neutralizing solution

Procedure:

1. Pour exactly 25 ml. of clear sample into Erlenmeyer flask.

2. Add exactly 5 ml. of reversion acid.

3. Heat to boiling over a gas burner and turn down heat so that the mixture just simmers for 15 minutes.

NOTE: If mixture evaporates to half the volume, add 5 ml. of distilled water.

4. Remove from burner and allow to cool to room temperature, then transfer to 25 ml. graduate.

5. Add 5 ml. of neutralizer.

6. Add distilled water to bring volume up to exactly 25 ml.

7. Perform orthophosphate test on this sample.

8. Record results of total phosphates as $PO_4$ = ____________PPM.

c. Polyphosphates:

Total phosphates minus orthophosphates = ______________ polyphosphates as $PO_4$.

## RELATIVE STABILITY

Purpose of Test: To determine the percent ratio of oxygen available in a sample to the total oxygen required to satisfy the BOD of a sample.

Method of Testing: Comparing time required for depletion of oxygen in an incubated sample to a prepared chart which shows the relative stability as related to time.

Principles of Test:

1. Methylene blue added to a sample containing available oxygen will cause the sample to turn blue.

2. Bacteria will use up the available oxygen during incubation and the blue color will disappear.

3. A conversion chart has been constructed by laboratory testing that relates time to percentage of total BOD satisfied.

Equipment:

1. BOD bottle (300 ml.)
2. Pipette
3. Incubator

Reagents:

Methylene blue dye

Procedure:

1. Fill BOD bottle with sample.

2. Add 0.8 ml. methylene blue from a pipette, extending tip just below surface of sample.

3. Insert stopper so that no air is trapped beneath it.

4. Place bottle in incubator adjusted for 20°C.

5. Observe bottle at the same hour daily and record the number of days it takes for the blue color to disappear.

6. Use chart to convert time to percent relative stability. Record results.

| Days Required at 20°C for Disappearance of Color | Relative Stability (Percent) |
|---|---|
| 0.5 | 11 |
| 1 | 21 |
| 2 | 37 |
| 3 | 50 |
| 4 | 60 |
| 5 | 68 |
| 6 | 75 |
| 7 | 80 |
| 8 | 84 |
| 9 | 87 |
| 10 | 90 |
| 11 | 92 |
| 12 | 94 |
| 13 | 95 |
| 14 | 96 |
| 16 | 97 |
| 18 | 98 |
| 20 | 99 |

# DISSOLVED SILICA (TAYLOR)

Purpose of Test: To determine the silica content of a water sample.

Method of Testing: Visual color comparison

Principles of Test:

1. Ammonium molybdate at an approximate pH of 1.2 reacts with dissolved silica to form molybdosilic acid which produces a yellow color proportional to the silica content of the sample.

2. The yellow color developed is compared to silica color standards to find the PPM silica present.

Equipment:

1. Taylor water analyzer
2. Silica color standard slide. 0-25 PPM $SiO_2$
3. Three Nessler tubes (150 mm)
4. Polyethylene graduated cylinder (100 ml.)
5. Pipette

Reagents:

Acidified ammonium molybdate solution

Procedure:

1. Transfer 50 ml. of clear sample into graduated cylinder.

2. Add 5 ml. molybdate reagent and mix thoroughly. Allow to stand 15 minutes (not over 20).

3. Fill two of the Nessler tubes to the mark with clear unheated sample and place in the outer slots of the analyzer.

4. Place the tube with treated sample in the center slot of analyzer.

5. Place color standard slide in the slot of the analyzer base.

6. Position the analyzer under a bright light so that the reflections in the mirror are clearly visible.

7. Match the arrows on the slide and base and shift slide from arrow to arrow until the best match between the center reflection (sample color) and an outer color (STD color) is made.

8. Read the slide and record the results as follows: __________ PPM $SiO_2$.

# DISSOLVED SOLIDS

**Purpose of Test:** To determine that portion of total solids in a sample which is dissolved.

**Method of Testing:** The normal procedure is to perform a total solids test and a suspended solids test and subtract the suspended solids from total solids.

Total solids in PPM
(minus) Suspended solids in PPM
Dissolved solids in PPM

Example:
68 PPM (total solids)
42 PPM (suspended solids)
26 PPM (dissolved solids)

## SETTLEABLE SOLIDS

Purpose of Test: To determine the volume of solids which will settle out of a sewage sample in order to determine the efficiency of sedimentation tanks and the approximate volume of sludge to be pumped.

Method of Testing: Settling sample in an Imhoff cone for a given period of time.

Principles of Testing:

1. Solids which will settle in a settling tank with normal detention time should settle under still conditions in one hour.

2. Slight agitation at the end of the 45 minutes will allow solids which stick to the cone to settle down in 15 minutes.

3. The Imhoff cone contains 1000 ml. and the bottom is graduated in ml. so the results can be expressed as ml. per liter.

Equipment:

1. Imhoff cone
2. Imhoff cone stand

Procedure:

1. Fill Imhoff cone to the 1000 ml. mark with well mixed sample and place in the stand.

2. Allow sample to stand for 45 minutes.

3. Lift cone and rotate back and forth 2 or 3 times.

4. Allow to stand for 15 minutes.

5. Read the cone at solids level and record as follows: ________ ml. per liter setteable solids.

## SUSPENDED SOLIDS

Purpose of Test: To determine that portion of solids in a sewage sample which are not dissolved.

Method of Testing: Gravimetric following filtration.

Principles of Test:

1. Suspended solids will be retained on a suitable filter and dissolved solids will pass through.

2. After drying and weighing, the weight of suspended solids is converted to PPM using the following formula:

$$\frac{\text{Wt X 1,000,000}}{\text{ml. sample}} = \text{PPM}$$

Equipment:

1. Graduated cylinder
2. Filter crucible
3. Suction apparatus
4. Drying oven
5. Tongs
6. Dessicator
7. Analytical balance

Reagents and Supplies:

Asbestos emulsion

Procedure:

1. Develop an asbestos mat approximately 3/16 inch thick in a filter crucible as follows:
    a. Place crucible on suction flask and fill with asbestos emulsion. Let stand 1 minute.
    b. Apply suction to flask and add sufficient emulsion to form mat, approximately 25 ml.
    c. Pour 25 ml. distilled water in crucible and vacuum it dry.

2. Place crucible with mat in drying oven at 103°C. and leave for one hour.

3. Remove crucible from oven, place in dessicator to cool.
CAUTION: Tongs must be used to handle hot equipment and also to prevent contamination from handling.

4. Weight crucible with mat. Record weight.

5. Measure 25 ml. of raw sewage or 50 ml. of settled sewage or 100 ml. of plant effluent and filter.
NOTE: After filtering sample, rinse graduated cylinder used to measure sample and filter.

6. Dry filter and residue in oven for one hour.

7. Cool in dessicator.

8. Weight and record it.

9. Compute weight of solids as follows: Weight of crucible, mat, and solids (step 8) minus weight of crucible and mat (step 4) = weight of suspended solids.

10. Convert weight of suspended solids to PPM and record results. See principles of test No. 2.

# TOTAL SOLIDS

Purpose of Test: To determine the total solids content of sewage sludge or water samples.

Method of Testing: Gravimetric determination following drying.

Principles of Test:

1. Most of the water is removed from the sample by a steam bath to prevent solids from caking to drying dish or forming moist pockets which are hard to dry.

2. Drying in an oven at 103° C. will remove remaining free water without causing volatilization of the solids.

Equipment:

1. Evaporating dish
2. Graduated cylinder or pan scales
3. Analytical balance
4. Drying oven
5. Tongs
6. Dessicator
7. Steambath

Procedure:

1. If sample contains small amounts of solids, place clean evaporating dish in oven and dry for one hour. (Dish used from sludge samples does not need oven drying).

2. Remove dish from oven and let cool in dessicator.
CAUTION: Use tongs when handling equipment from oven or from dessicator to prevent burns and to prevent contamination of equipment until it has been weighed.

3. Weigh clean dry dish on analytical balance and record weight.

4. Measure 50 ml. of sample and transfer to evaporating dish. Sludge samples may be added by weight using pan balance.

5. Place evaporating dish with sample on steam bath and evaporate until hard.

6. Transfer dish to drying oven and dry at 103° C. for one hour.

7. Transfer dish to dessicator to cool.

8. Weigh dish with dry sample. Save this sample if volatile solids are to be determined.

9. Compute results as follows:

Wt of dish with dry solids - weight of dish X 1,000,000 = ml.
PPM total solids. or grams of sample

10. Record results: ________________PPM total solids.

## VOLATILE AND FIXED SOLIDS

Purpose of Test: To determine that portion of sewage or sludge solids which is volatile or decomposable and is mostly organic material, and to determine that protion which is fixed or nondecomposable inorganic material.

Method of Testing: Gravimetric

Principles of Test:

1. Total solids are first determined by evaporation of water and and wighing the residue. See total solids test.

2. The organic or volatile solids are decomposed in a muffle furnace at 600° C. At this temperature the inorganic material will not burn.

3. The weight of total solids, volatile solids, and fixed solids are determined as follows:

   a. Weight of evaporating dish with dried sample minus wei weight of evaporating dish = weight of volatile solids.

   b. Weight of evaporating dish with dried solids minus weight of dish and ash after burning = weight of volatile solids.

   c. Weight of dish and ash minus weight of dish = weight of fixed solids.

4. Weight of each type of solid is converted to PPM by the formula:

$$\frac{\text{Wt of solid X 1,000,000}}{\text{ml. of sample}} = \underline{\hspace{2cm}} \text{ PPM}$$

Equipment:

1. All equipment needed for total solids test
2. Muffle furnace
3. Asbestos gloves
4. Tongs

**Reagents:** None

**Procedure:**

1. Determine the total solids for a sample (see total solids test).

2. Place evaporating dish with total solids residue in a muffle furnace at 600° C. and leave for approximately 15 minutes.
   CAUTION: Asbestos gloves and long tongs are necessary when placing equipment in or removing equipment from furnace to prevent burning hands and arms.

3. Remove dish from furnace and place in dessicator to cool.

4. Weigh dish with fixed solids on analytical balance.

5. Compute results as indicated under principles 3 and 4 and record results as follows:

   Volatile solids = ________________PPM

   Fixed solids = _________________ PPM

## SPECIFIC CONDUCTANCE

Purpose of Test: To measure the specific conductance of a water sample as a relative measure of the dissolved ionizable solids as NaCl equivalent.

Method of Testing: Electric Conductivity Meter

Principles of Test:

1. Water without any dissolved solids is a very poor conductor of electricity.

2. Water which contains dissolved ionizable solids will conduct electricity in approximate proportion to the concentration of the ions.

3. A conductivity meter is used to measure the micromhos conductivity.

Equipment:

1. Solo-bridge (specific conductivity meter).
2. Proper conductivity cell probes as follows:
    a. Low range probes for distilled or demineralized water samples.
    b. High range probes for raw or treated water samples.

3. Two, footed cylinders (beakers may be used if sufficiently deep enough to allow submergence of air vent on probes).

4. Conversion chart.

Reagents: None except for pH adjustment of boiler water. Refer to Bureau of Mines Instruction.

Procedure:

1. Fill footed cylinders two thirds full of sample.

2. Select probes with high or low range depending on sample.

3. Rinse the probes in one of the cylinders of sample.

4. Place probes in second cylinder.

5. Plug in the meter and turn switch to "ON" position.

6. Check temperature of sample used to rinse probes.

7. Set temperature control on meter to temperature obtained in step 6.

8. Jiggle the probes in sample until all of the air bubbles escape through the vent holes. Keep probes submerged below vent hole level.

9. Turn the conductivity scale knob until the dark area of the eye or null indicator is at its widest size.

10. Read the meter and record the micromhos specific conductivity of sample. NOTE: If high range probes are used, the meter reading must be multiplied by 10.

11. Turn switch to the off position and unplug the meter.

12. Rinse the probes in distilled water and store.

13. Use the conversion chart that is furnished with the meter to convert specific conductivity to PPM NaCl equivalent.

14. Record results:

____________________Micromhos specific conductivity.

____________________PPM NaCl equivalent.

## SULFATE (BETZ)

Purpose of Test: To determine the sulfate ion ($SO_4^=$) concentration in a water sample.

Method of Testing: Volumetric titration using a color indicator, THQ, for end point determination.

Principles of Test:

1. In a solution of slightly acidified sample and alcohol to which THQ indicator has been added, barium chloride will precipitate sulfate ions as barium sulfate.

2. An excess of barium chloride will react with the THQ indicator resulting in a color change from yellow to rose red.

3. Silver nitrate is added to sharpen end point.

Equipment:

1. Burette
2. Graduated cylinder (50 ml.)
3. Erlenmeyer flask (125 ml.) or casserole
4. Chemical scoop
5. Pipette

Reagents:

1. 0.1N hydrochloric acid
2. 0.1N sodium hydroxide
3. Phenolpthalein indicator solution
4. THQ indicator
5. Isopropyl alcohol
6. Silver nitrate, 2% or N/58.5

Procedures:

1. Measure 25 ml. of the clear sample and pour it into an Erlenmeyer flask.

2. Add 3 drops of phenolpthalein indicator. If the sample does not turn pink, add 0.1N sodium hydroxide until pink color appears.

3. Add 0.1N hydrochloric acid (a drop at a time) until pink color disappears.

4. Add 25 ml. of alcohol.

5. Add one scoop of THQ indicator.

6. Add one ml. of silver nitrate.

7. Titrate with barium chloride until color changes from yellow to red. This is the end point.

8. Compute and record results as follows:

____________ PPM $SO_4$= _______________ ml. $BaCl_2$ times 48.

NOTE: If sulfites or phosphates are present, check BETZ handbook for alternate methods.

## SULFITE TEST (STD METHODS)

Purpose of Test: To determine the sodium sulfite concentration of boiler water.

Method of Testing: Volumetric titration

Principles of Test:

1. Sulfites in an acidified water sample are oxidized by titrating with potassium iodide-iodate solution.

2. When all of the sulfites are oxidized, free iodine is released, which, in the presence of starch, causes a blue color. The appearance of the blue color is in the end point of the titration.

Equipment:

1. Erlenmeyer flask (250 ml.)
2. Graduated cylinder (50 ml.)
3. Burette
4. Pipette

Reagents:

1. Sulfuric acid (1:1)
2. Starch indicator solution
3. 0.0125N potassium iodide-iodate

Procedures:

1. Measure and pour 50 ml. of cool unfiltered sample into the 250 ml. flask.

2. Add 1 ml. sulfuric acid to the flask.

3. Add 1 ml. starch indicator solution to the flask.

4. Titrate with potassium iodide-iodate until a faint permanent blue color develops.

5. Compute PPM sodium sulfite as follows and record results: ml. reagent X 15.7 = PPM sodium sulfite.

## TANNIN

Purpose of Test: To determine the concentration of tannin in boiler water.

Method of Testing: Visual color comparison

Principles of Test:

1. The concentrations of tannin used for boiler water treatment impart a brown color to its water.

2. The intensity of the color developed is compared to standard colors.

Equipment:

1. Hellige tannin color comparator
2. Three comparator tubes
3. Small beaker (for sample)

Reagents: None

Procedure:

1. Fill two of the comparator tubes with the untested water.

2. Place tubes with the untreated water in the outer compartments of the comparator.

3. Fill the third tube with boiler water sample, and place it in the center compartment.

4. Select standard color which matches color of sample.

5. Record below the name and number of the standard which matches the sample. Tannin matches ________________ color standard.

## TASTE AND ODOR (THRESHOLD NUMBER)

Purpose of Test: To determine the intensity (threshold number) of the taste and odor from a water sample.

Method of Testing: Subjective human response to taste and odor sensation from diluted sample.

Principles of Test:

1. Taste and odor are separate sensations which may be caused by individual substances or several substances. There is no practical test which can be correlated to their intensity. The intensity of the sensation of tastes and odor depends on the concentration of the substances and the temperature of the sample.

2. Several samples are diluted with odor and taste free water at different ratios, brought to standard temperature of 40 degrees C., and tasted or smelled. The ratio of the dilution, $\frac{\text{ml. sample + ml. dilution}}{\text{ml. of sample}}$ is the threshold number for taste.

   CAUTION: Be sure that samples to be tasted are safe to take into the mouth.

3. The diluted samples are then brought to $60^{\circ}$ C. temperature and smelled to determine the threshold number for odor and taste.

4. Since one individual's sensitivity to taste and odor varies from day to day, and is subjective, and differs from another person's, three or more persons should do the tasting and smelling to determine the average threshold number.

Equipment:

1. Seven 500 ml. glass stoppered Erlenmeyer flasks
2. Graduated cylinder (100 ml.)
3. Pipette
4. Hot plate or water bath
5. Thermometer

Reagents: Odor and taste free water

Procedure:

1. Add sample of odor and taste free water to seven Erlenmeyer flasks as shown by the following table to give threshold numbers as indicated:

| *Flask No. | ml. sample | ml. taste and odor free water | Resultant Threshold No. |
|---|---|---|---|
| 1 | 200 | 0 | 1 |
| 2 | 50 | 150 | 4 |
| 3 | 12 | 188 | 17 |
| 4 | 2.8 | 197.2 | 70 |
| 5 | 0 | 200 | Blank |
| 6 | 0 | 200 | Blank |
| 7 | 0 | 200 | Blank |

*The flask should be coded so that the tasters will not know which is which.

2. Warm the flask to [illegible]0° C.

3. Arrange the flask in order of sample strength and place blanks at random between them so that the taster will not know which are blanks.

| EXAMPLE: | 1 | 5 | 6 | 2 | 7 | 3 | 4 |
|---|---|---|---|---|---|---|---|
| | B | S | B | S | S | B | S |

4. Have the tasters, individuals who do not know the order of the samples, taste the samples, starting with a blank or the most dilute sample and progressing to the more concentrated. Have the tasters indicate which samples have taste and which do not.
CAUTION: Be sure the water is safe to taste.
NOTE: The water need not be swallowed.

5. Determine the taste threshold number of the weakest dilution in which the tasters could detect taste by referring to the chart in step 1 of the procedure.

6. Warm the samples in the flasks to 60° C. and check for odor threshold number as for taste except that the samples will be checked by smelling.

7. Record results as follows:

a. Taste Threshold Number = ______________________

b. Odor Threshold Number = ______________________

NOTE: More exact taste and odor numbers may be obtained by running tests on a broader range of dilutions within the range found in this test. The taste and odor numbers are computed as follows:

$$\frac{\text{ml. sample + ml. dilution water}}{\text{ml. sample}} = \text{Taste or Odor numbers}$$

# TEMPERATURE

Purpose of Test: To determine the temperature of water using both the Centigrade and Fahrenheit scales.

Method of Testing: Mercury Thermometer.

Principles of Test:

1. All bodies of matter have the capacity to transfer heat energy by radiation, conduction and convection to a body of lower heat level or to absorb heat from a body of higher heat level until both bodies reach the same temperature.

2. In the mercury thermometer, heat is transferred from the sample to the mercury.

3. As the temperature of the mercury changes, its volume changes. An increase in the temperature expands the mercury and causes it to rise in the tube. A decrease in temperature causes the mercury to contract and lower its level.

4. On the Centigrade scale thermometer, the mercury level point, at which water freezes is marked $0^{\circ}$ and the point at which water boils is marked $100^{\circ}$ with graduations between, above, and below these points being 1/100 of the difference between the $0^{\circ}$ and $100^{\circ}$ mark.

5. On the Fahrenheit scale thermometer, the freezing point is marked $32^{\circ}$ and the boiling point is marked $212^{\circ}$. The graduations are 1/180 of the distance between these points.

6. The temperature in one scale can be converted to the temperature on the other scale using the following formulas:

$$F = 9/5C + 32$$
$$C = 5/9\ (F - 32)$$

Equipment:

1. Mercury thermometer
2. 500 ml. beaker

**Reagents:** None

**Procedure:**

CAUTION: The thermometer is easily broken by careless handling or by being exposed to heat greater than that for which it is designed. The mercury is also toxic if it gets in open cuts or is swallowed.

1. Fill beaker three fourths full of sample.

2. Place the thermometer, mercury end down, in the beaker and allow it to lie against the side of the beaker.

3. Wait three minutes and read the thermometer at the mercury level. NOTE: It is best to read the thermometer without removing it from the beaker. If you do remove the thermometer to read it, do not touch the mercury-filled end.

4. Leave thermometer in beaker and re-read at one minute intervals until the last two readings are the same.

5. Record the reading as ________ degrees __________ scale (scale, thermometer used).

6. Convert the reading to the other scale and record as: ____________ degrees ____________ scale (alternate scale).

## PROCEDURES FOR VOLUMETRIC TITRATION

**Purpose of Exercise:** To develop skills and techniques used in measuring impurities in water samples and in standardizing reagents by volumetric titrations.

Principles of Volumetric Titrations:

1. A reagent of known concentration, which will react with the impurity in the sample being tested, is added to the sample until one drop of excess reagent produces an observable reaction or change which indicates that all of the impurity has entered into the reaction. This observable reaction or change is known as the end point of the titration.

2. The end point may be indicated by one of the following changes:

   a. A change in color of an added organic dye. Usually due to a change in pH.

   b. A change in pH as measured by a pH meter.

   c. A change in oxidation reduction potential measured by an electrical potentiometer.

   d. A color change produced by an element, ion, or compound formed or removed at the completion of the reaction.

3. After the amount of reagent used is determined, the amount of the impurity in the sample is computed by one of the following methods:

   a. The ml. of reagent x factor for given test = PPM unknown.

   b. $$\frac{\text{The ml. R x NR x Milliequivalent wt x 1,000,000}}{\text{mo. sample of sample used}} = \text{PPM unknown.}$$

where

R = Reagent
N = Normality of Reagent
Milliequivalent wt is that of the chemical form in which the unknown is expressed.

4. The Normality of a reagent being standardized may be computed using the formula:

$$\text{ml. Reagent}_1 \times \text{Normality Reagent}_1 = \text{ml. Reagent}_2 \times \text{Normality Reagent}_2$$

NOTE: Free mineral acid test is used for this exercise since it is representative of the various titration techniques.

Equipment:

1. Automatic burette assembly complete with burette, burette bottle, two hole rubber stopper, rubber pressure bulb and tube.

   NOTE: Squeeze bottle, straight burette or pipettes may be used with slight modification in step by step procedures.

2. Erlenmeyer flask (Casserole and glass stirring rod may be used for some tests).

3. Graduate cylinder

Reagents:

1. Standard solution - 0.02N NaOH
2. End point indicator - Methyl orange
3. Stopcock lubricant

Procedures:

1. Fill burette bottle with standard reagent (0.02N sodium hydroxide). NOTE: This step will be performed by, or under the direction of the instructor.

2. Check stopcock for free movement. It should turn easily using two fingers and applying slight pressure. Do not push down on the stopcock as this will cause it to freeze. Do not pull up on it to turn it as this will allow reagent to be lost. If the stopcock does not turn easily, lubricate it as follows:

a. Remove the small washer on bottom of the stopcock and remove it from burette.

b. Apply a small film of lubricant above and below the small hole in the stopcock. Do not apply lubricant where it can get in the hole.

c. Replace stopcock and washer and check to see if the hole is clear. Note position of stopcock when closed, open, and partially open.

3. Close stopcock, place a finger over the small hole in the glass filling tube and press the bulb slowly to fill the burette with sufficient reagent to rinse the walls of the burette. CAUTION: Do not press bulb too hard; it will cause spillage of reagent.

4. Drain the reagent from burette, refill part way, and drain enough to remove air from the burette tip.

5. Fill burette slowly until it over flows back into the bottle.

6. Read the burette, at the point of reagent level. It should read 0 ml. NOTE: Each number on the burette represents 1 ml.; each mark between numbers represents .1 ml. Liquids will not stand with a flat surface in the burette but will form a slight dish shape called the meniscus. The bottom of the meniscus is used to determine the level of liquid. Make sure the level is read with your eye in the same horizontal plane as the graduation being read.

7. Measure 50 ml. of sample with graduate cylinder and pour into the Erlenmeyer flask.

8. Place flask under the burette tip and add reagent slowly (rapid drops). Rotate flask gently so contents will mix. When reagent causes a temporary color change as it strikes sample, slow the addition of reagent to a drop at a time until the end point is reached (sample turns straw yellow).

9. Read the burette at the liquid level and record ml. reagent used.

10. Compute the PPM impurity (FMA as $CaCO_3$) using a factor (20) as shown in principle 3a.

11. Compute the PPM inpurity (FMA as $CaCO_3$) as shown in 3b. Use .050 as milliequivalent wt of $CaCO_3$.

12. Record results.
NOTE: Results are not recorded correctly unless correct unit of measures is shown.

13. If equipment is to be stored, drain reagent from burette and rinse with distilled water.

# TURBIDITY

Purpose of Test: To measure the cloudy condition of water due to the suspended solids in the water.

Principles of Test:

1. Clear water will allow light to pass through it in a straight line.

2. The suspended solids in water will absorb or diffuse light.

3. The absorption and diffusion ability of a sample is measured by determining the depth of the sample needed to mask the image of a standard candle flame.

Equipment:

1. Jackson turbidity meter
2. Standard candle
3. Jackson turbidity tube, glass
4. Beaker

Reagents: None

Procedures:

1. Lift the black metal tube from the stand and replace in an upright position.

2. Check the candle to see if it is flush with top of its holder.

   a. If flush, continue to step 9.
   b. If candle is not flush, continue to step 3.

3. Light the candle.

4. Remove the upper position of candle holder.
   NOTE: The candle holder may be lifted from the base for easier handling.

5. After the candle has burned enough to warm its holder, apply light pressure to base of the candle to force the top flush with holder.

6. Extinguish flame.

7. Reassemble the holder and return it to the stand.

8. Allow candle and holder to cool.

9. Remove any portion of the wick which can be removed with fingers.

10. Obtain approximately 200 ml. of sample.
NOTE: The sample should not contain rapidly settling or floating material.

11. Pour one inch of sample into the glass tube to prevent heat breakage.

12. Place tube in the holder.

13. Light the candle and allow flame to stabilize.
NOTE: Eliminate any draft which causes the flame to flicker.

14. Stir sample and add it slowly to the glass tube until the image of the candle flame, as viewed while looking downward through the tube, disappears.

15. Read the calibrated glass tube at the level of the sample.

16. Record the reading: Units Turbidity = ______________________.

NOTE: If sample shows less than 25 units turbidity, the turbidity should be checked by comparison with standard diluted samples. These samples are made from a more turbid suspension which has been checked by the above procedure.

3TPT-5111-01

Technical Training

# Basic Mathematics - Fractions

17-4

April 1967

SHEPPARD AIR FORCE BASE

Original Material Prepared
by
Naval Air Technical Training Command

**Designed For ATC Course Use**

## ANSWERS TO SELF-TEST

1. A fraction is part of a whole.

2. 7— Numerator. Indicates how many parts of the whole are being considered.
   8— Denominator. Indicates how many equal parts the whole has been divided into.

3. a. P b. I c. M d. I e. M f. I g. P h. P i. M j. P

4. a. $\frac{11}{3}$ b. $1\frac{1}{10}$ c. $\frac{64}{5}$ d. $1\frac{4}{15}$ e. $\frac{63}{8}$

5. a. $\frac{2}{9}$ b. $\frac{3}{4}$ c. $\frac{1}{3}$ d. $\frac{3}{7}$ e. $\frac{2}{3}$ f. $\frac{1}{4}$

6. a. 1 b. $\frac{1}{21}$ c. $1\frac{1}{8}$ d. $\frac{3}{4}$ e. $1\frac{9}{10}$ f. $41\frac{1}{16}$

7. a. $\frac{1}{4}$ b. $65\frac{1}{3}$ c. $4\frac{1}{8}$ d. 2

8. a. 2 b. $3\frac{4}{7}$ c. $\frac{3}{8}$ d. $\frac{12}{37}$

## INSTRUCTIONS

1. This is not a test. This is a learning situation. In this Programmed Lesson on fractions, you will be learning at your own speed.

2. Two types of programming are used in this lesson:

    a. LINEAR-- In this portion, you will go from "frame" to "frame", using a provided cardboard to cover upcoming frames and answers. In each frame, you are given information and then a question to answer or a problem to solve. Your answer can be checked to the left of the next frame. "Peeking" is not an advantage. If you make an error, strike out your incorrect answer, reread the frame, and write the correct answer.

    b. SCRAMBLED-- In this portion, you will be given problems to solve and asked to select the answer from a list of answers. Circle the answer you choose and go to the page as your answer directs. Follow directions closely. If you select an incorrect answer, do not erase, but put a "X" through the circle. Rework the problem again and circle another answer.

3. READ ALL INFORMATION CAREFULLY. BE SURE YOU UNDERSTAND WHAT IS SAID BEFORE YOU TRY TO ANSWER THE QUESTION. If you wish, you may turn back in the program for review at any time.

4. Turn to page iii for the objectives.

## FRACTIONS

### OBJECTIVES

1. Define a fraction.
2. Identify the two parts of a given fraction and explain what each part shows.
3. Identify proper fractions, improper fractions, and mixed numbers from a given list.
4. Change a given list of improper fractions to mixed numbers and mixed numbers to improper fractions.
5. Reduce a list of fractions to their lowest terms.
6. Solve problems in addition and subtraction of fractions. Answers must be in lowest terms.
7. Solve problems in multiplication of fractions, cancelling where applicable. Answers must be in lowest terms.
8. Solve problems in division of fractions, cancelling where applicable. Answers must be in lowest terms.

NAME ____________________

CLASS ____________________

START THE PROGRAM ON PAGE 1.

SUGGESTED READING TIME 100 MINUTES

| | |
|---|---|
| | 1. A fraction is a part of a whole. $\frac{3}{4}$ is a fraction and therefore is a part of a ____________. |
| whole | 2. Part of a whole is the definition of a<br>____________. |
| fraction | 3. The definition of a fraction is stated as:<br>____________ of a ____________. |
| part<br>whole | 4. Define a fraction.<br>________________________________________. |
| part of a whole | 5. Fractions have two parts— a numerator (above the line) and a denominator (below the line).<br>Example: $\frac{3}{8}$ —numerator / —denominator<br>In the fraction $\frac{2}{3}$, the number 3 below the line is the ____________ and the number 2 above the line is the ____________. |
| denominator<br>numerator | 6. All fractions have denominators and numerators. In the fractions $\frac{2}{3}$ and $\frac{11}{12}$, the 3 and 12 are ____________ and the 2 and 11 are<br>____________. |

Continue to page 3

2A

Wrong! 12 x 3 = 36, but you must now do step 2. Add this product (36) to the numerator; retain the denominator to get the improper fraction. Go back to page 11, Frame 29, and select another answer.

2B

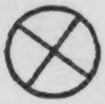
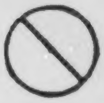
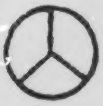
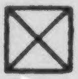
Nope! You will still have to go to lower terms. You reduced by dividing two into the numerator and denominator but you must now find a number to further reduce $\frac{21}{27}$ and then you'll have it. Return to page 16A, select the other answer, and continue.

2C

$\frac{2}{5}$ is the correct answer.

Now try another problem. $\frac{3}{8} \div \frac{2}{3} =$ _____

| If your answer is: | Go to page: |
|---|---|
| $\frac{1}{4}$ | 18C |
| 4 or $\frac{4}{1}$ | 26B |
| $\frac{9}{16}$ | 28B |

| | |
|---|---|
| denominators<br>numerators | 7. The denominator tells how many equal parts the whole has been divided into. In the fraction $\frac{9}{10}$, the denominator indicates the whole has been divided into _____ equal parts. |
| 10 | 8. Under the figures below, write the number that would be used as the denominator of a fraction.<br>   <br>a. _______ b. _______ c. _______ d. _______ |
| a. 4<br>b. 2<br>c. 3<br>d. 4 | 9. In the fraction below, circle the denominator and explain what it indicates.<br>$\frac{15}{16}$ ________________________________________<br>________________________________________ |
| 16 denominator<br>Tells (indicates) how many parts the whole has been divided into. | 10. The numerator (number above the line) of a fraction shows "how many parts of the whole are being considered." In the fraction $\frac{2}{3}$, the numerator indicates that _____ parts of the whole are being considered and the denominator indicates that the whole has divided into _____ equal parts. |
| 2<br>3 | 11. In the fraction $\frac{13}{14}$, the number of parts being considered is _____ and the part of the fraction that tells us this is called the ___________. |

Continue to page 5

4A

Wrong! Multiplication and addition are correct but you must place this sum over the denominator of the fraction. Return to page 11, Frame 29, and select another answer.

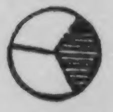
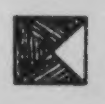
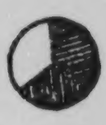
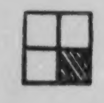
4B

Right! Now try this. Reduce $\frac{14}{56}$ to its lowest term.

| If your answer is: | Go to page: |
|---|---|
| $\frac{1}{4}$ | 6B |
| $\frac{7}{28}$ | 8B |

4C

No! You forgot to obtain the reciprocal of the divisor (invert the divisor), before you multiplied. Go back to page 27, frame 57; review the procedure again, then rework the problem from frame 59 again and select the correct answer.

| | |
|---|---|
| 13<br>numerator | 12. The number of parts being considered is indicated by the ____________ of a fraction. |
| numerator | 13. Under the figures below, write the fractions.<br>The number of parts being considered are shaded.<br>   <br>a. _______ b. _______ c. _______ d. _______ |
| a. $\frac{1}{3}$<br>b. $\frac{3}{4}$<br>c. $\frac{2}{3}$<br>d. $\frac{1}{4}$ | 14. In the fraction below, write what each number is called and what it indicates: $\frac{6}{7}$<br>6 --______________________________<br>______________________________<br>7 --______________________________<br>______________________________ |
| 6 numerator. Indicates how many parts of the whole are being considered<br>7 denominator. Indicates how many equal parts the whole has been divided into. | 15. There are three types of common fractions--proper, improper, and mixed numbers. The three types of common fractions are mixed numbers, ____________ and ____________ fractions. |
| proper<br>improper<br>(either order) | 16. The difference between proper and improper fractions is the size of the numerator. The numerator of an improper fraction is always the same as or larger than the denominator; therefore, in a proper fraction, the numerator is ____________ than the denominator. |

Continue to page 7

6A

Correct. Now change $15\frac{1}{5}$ to an improper fraction.

| If your answer is: | Go to page: |
|---|---|
| $\frac{76}{5}$ | 8A |
| $\frac{75}{5}$ | 10A |

6B

Good! You might have started with dividing by two (2) and doing several steps, but 14 divides into 14 and 56 evenly. To reduce an improper fraction such as $\frac{8}{4}$ or $\frac{9}{5}$, you simply divide the denominator into the numerator. Reduce $\frac{9}{5}$ to its lowest terms.

| If your answer is: | Go to page: |
|---|---|
| $\frac{9}{5}$ | 10B |
| $1\frac{4}{5}$ | 12B |

| | |
|---|---|
| smaller (less than) | 17. $\frac{7}{8}$ is a proper fraction because the ____________ is ____________ than the denominator. |
| numerator<br>smaller (less) | 18. $\frac{8}{7}$ and $\frac{8}{8}$ are improper fractions because the ____________ are ________________________ than the denominators. |
| numerators<br>are same as or greater (are the same as or larger) | 19. In the list below, place a "P" by the proper fractions and "I" by the improper fractions.<br>a. $\frac{12}{17}$ c. $\frac{4}{5}$<br>b. $\frac{9}{7}$ d. $\frac{12}{12}$ |
| a. P c. P<br>b. I d. I | 20. A mixed number is a whole number combined with a proper fraction. $3\frac{5}{6}$ is a whole number (3) and a proper fraction $\frac{(5)}{(6)}$; therefore, $3\frac{5}{6}$ is a ____________. |
| mixed number | 21. To review definitions, match the following types of fractions with the correct statement or statements by writing the letter of the statement by the number of the fraction. All letters are to be used.<br>1. Proper fraction<br>2. Mixed number<br>3. Improper fraction<br>A. Numerator greater than the denominator<br>B. Numerator less than the denominator<br>C. Whole number and a proper fraction<br>D. Numerator equal to denominator |

Continue to page 9

8A

Right! $\frac{76}{5}$ is correct. You can check your answers by changing the improper fraction back to the mixed number. Change $7\frac{1}{4}$ to an improper fraction and check your answer.

$$7\frac{1}{4} = \underset{\text{(improper fraction)}}{\underline{\qquad\qquad\qquad}} = \underset{\text{(mixed number)}}{\underline{\qquad\qquad\qquad}}$$

Go to page 13, Frame 30, to check answer and continue from there.

8B

You reduced—but not to the lowest terms. Return to page 4B and find the number that will reduce the $\frac{7}{28}$ and then you'll have the correct answer that will allow you to continue.

| | |
|---|---|
| B. 1.<br>C. 2.<br>D,A 3. | 22. In the list below, place a "P" by the proper fractions, an "I" by the improper fractions, and a "M" by the mixed numbers.<br>a. $3\frac{1}{2}$ e. $\frac{22}{29}$<br>b. $\frac{9}{5}$ f. $\frac{7}{7}$<br>c. $12\frac{2}{3}$ g. $\frac{79}{75}$<br>d. $\frac{3}{4}$ |
| a. M e. P<br>b. I f. I<br>c. M g. I<br>d. P | 23. An improper fraction can be changed to a mixed number by dividing the denominator into the numerator. The fraction $\frac{21}{10}$ can be changed to a mixed number by dividing the numerator $\underset{\text{(number)}}{\underline{\qquad}}$ by $\underset{\text{(number)}}{\underline{\qquad}}$ the denominator. |
| 21<br>10 | 24. To change the improper fraction $\frac{21}{10}$ to a mixed number, follow two steps: (1) Divide the numerator by the denominator to get the whole number:<br>$\begin{array}{r l} 2 & \text{the whole number} \\ 10\overline{)21} & \\ \underline{20} & \\ 1 & \text{the remainder} \end{array}$<br>(2) Place the remainder over the denominator to get the proper fraction: $\frac{1}{10}$ the proper fraction.<br>Then $\frac{21}{10} = \underset{\text{(mixed number)}}{\underline{\qquad\qquad}}$ |
| $2\frac{1}{10}$ | 25. Now change the improper fraction $\frac{26}{5}$ to a mixed number. Show your work. $\overline{)\qquad}$ $\underset{\text{(mixed number)}}{\underline{\qquad\qquad}}$ |

Continue to page 11

10A

Wrong! You forgot to add the numerator to the product of the whole number times the denominator. If you now see your error, go back to page 6A and select the other answer and follow directions. If you need the rule again, return to page 11, Frame 28, and start again from there.

10B

No... To reduce an improper fraction, you simply change it to a whole number or to a whole number and a fraction (mixed number) by dividing the numerator by the denominator. Now go back to page 6B and reduce properly.

10C

Negative. You have simply added numerators, retained highest denominator, and reduced. You must change to equivalent fractions. Re-read rule on page 17, Frame 40, and rework problem from page 19, Frame 43, again.

| | |
|---|---|
| $\begin{array}{r} 5 \\ 5\overline{)26} \\ \underline{25} \\ 1 \end{array}$<br>$5\frac{1}{5}$<br>(mixed number) | 26. Try another. Change $\frac{54}{11}$ to a mixed number.<br>$\overline{)\quad\quad}$ = ____________. |
| $4\frac{10}{11}$ --if you missed this one, re-read and re-work Frames 22 thru 26, then continue. | 27. An improper fraction can be changed to a mixed number. So can a mixed number be changed to an improper fraction. Therefore, an improper fraction is interchangeable with a ____________ number. |
| mixed | 28. Changing mixed numbers to improper fractions requires three steps: Example: Change $4\frac{3}{5}$ to an improper fraction.<br>Step<br>(1) Multiply the whole number by the denominator of the fraction. $4 \times 5 = 20$<br>(2) Add the product to the numerator. $20 + 3 = 23$.<br>(3) Place the sum over the denominator of the fraction.<br>Then $4\frac{3}{5}$ = ____________ (improper fraction) |
| $\frac{23}{5}$ | 29. Change $12\frac{2}{3}$ to an improper fraction.<br>If your answer is: Go to page:<br>$\frac{36}{3}$ 2A<br>$\frac{38}{2}$ 4A<br>$\frac{38}{3}$ 6A |

12A

No! $\frac{2}{4}$ can be reduced to $\frac{1}{2}$ by dividing two (2) into both the numerator and denominator. Remember the rule, a fraction is in its lowest terms only when the number one (1) is the only number that divides evenly into both the numerator and denominator. Return to page 13, Frame 31, and select the correct answer.

12B

$1\frac{4}{5}$ is correct. If we ask you to reduce the fraction $\frac{8}{4}$, would you answer 2? You would have been correct there, too. Now turn to top of page 15, Frame 32, and continue the program.

12C

No. You've added numerators but have not changed fractions to equivalent fractions. Read rule again on page 17, Frame 40, then rework problem on page 19, Frame 43. Select another answer.

If you came to this page directly from the previous page, you have not followed the directions given in the previous frame. From this point (unless otherwise directed) in the lesson, you will proceed by the scrambled method. Do Not read the frames in sequence, but after selecting an answer, refer to the proper page or frame as directed. Return to page 11, Frame 29, check your answer, and refer to the page as directed.

---

$7\frac{1}{4} = \frac{29}{4}$

$\frac{29}{4} = 7\frac{1}{4}$

30. Change each of the following improper fractions to mixed numbers and the mixed numbers to improper fractions:

a. $1\frac{4}{9}$ c. $10\frac{11}{12}$

b. $\frac{21}{8}$ d. $\frac{49}{3}$

---

a. $\frac{13}{9}$

b. $2\frac{5}{8}$

c. $\frac{131}{12}$

d. $16\frac{1}{3}$

31. A fraction is in its lowest terms when the number one (1) is the only number that divides evenly into both the numerator and denominator. (NOTE: Dividing both the numerator and denominator by the same number does not change the value of the fraction) Select the fraction below that is in its lowest terms.

| If your answer is: | Go to page: |
|---|---|
| $\frac{2}{4}$ | 12A |
| $\frac{6}{9}$ | 14A |
| $\frac{3}{7}$ | 16A |

14A

Wrong! $\frac{6}{9}$ can be further reduced. Three (3) is the largest number that divides evenly into both the numerator (6) and the denominator (9). $\frac{6}{9}$, then, reduced to lowest possible terms, is $\frac{2}{3}$. Now return to page 13, Frame 31, and select the correct answer.

14B

Right! $1\frac{1}{4}$ is the correct answer. Try another, reduce to lowest terms.

Add $\frac{1}{2} + \frac{1}{2} + \frac{4}{5} + \frac{3}{20} =$ ____________

| If your answer is: | Go to page: |
|---|---|
| $1\frac{9}{10}$ | 18B |
| $1\frac{19}{20}$ | 20B |

| | |
|---|---|
| You came from page 12B. | 32. Reduce each of the following fractions to lowest terms:<br>a. $\frac{12}{4}$ =     c. $\frac{64}{72}$ =<br>b. $\frac{21}{49}$ =     d. $\frac{17}{51}$ = |
| a. 3 or $\frac{3}{1}$<br>b. $\frac{3}{7}$<br>c. $\frac{8}{9}$<br>d. $\frac{1}{3}$ | 33. To add or subtract fractions, they must be like fractions. Like fractions have the same number for a denominator. $\frac{7}{12} + \frac{5}{12}$ or $\frac{7}{12} - \frac{5}{12}$ are like fractions because they have the same number for a ____________. |
| denominator | 34. Fractions must have like (common) denominators before you can ____________ or ____________ them. |
| add<br>subtract<br>(any order) | 35. When fractions have common denominators, you add or subtract numerators and retain the common denominator.<br>Example: $\frac{7}{12} + \frac{5}{12} = \frac{12}{12}$ reduced = 1<br>Then $\frac{7}{12} - \frac{5}{12}$ = ____________ reduced = ________. |
| $\frac{2}{12}$<br>$\frac{1}{6}$ | 36. Before fractions with unlike denominators can be added or subtracted, they must be changed to their lowest common denominator (LCD). LCD is the lowest number that is divisible by each denominator. Example: $\frac{2}{5} + \frac{1}{20}$ or $\frac{2}{5} - \frac{1}{20}$<br>The lowest number divisible by each denominator is 20; therefore, 20 is the ____________. |

Continue to page 17

16A

$\frac{3}{7}$ is correct. One (1) is the only number that divides evenly into both 3 and 7.

Let's try a larger fraction. Reduce $\frac{42}{54}$ to its lowest terms.

| If your answer is: | Go to page: |
|---|---|
| $\frac{21}{27}$ | 2B |
| $\frac{7}{9}$ | 4B |

16B

No. Not quite. Your addition is correct but you must have overlooked the "reduce answers to lowest terms." Go back to page 19, Frame 43, reduce, and pick the correct answer.

16C

$\frac{6}{15}$ is wrong. You borrowed one (1) from 16, which gave you the fraction $\frac{15}{15}$, but now you must add $\frac{15}{15} + \frac{8}{15}$, then do your subtraction. Return to page 20A, rework the problem, and select another answer.

| | |
|---|---|
| least or lowest common denominator or (LCD) | 37. Again, the lowest number divisible by each denominator of fractions to be added or subtracted is called the ____________. |
| LCD | 38. Determine the lowest common denominator (LCD) for these fractions: $\frac{1}{2} + \frac{1}{4}$ , the LCD is _____.<br>$\frac{2}{7} - \frac{1}{42}$ , the LCD is _____. |
| 4<br>42 | 39. Find the LCD for the fractions below:<br>a. $\frac{5}{8} + \frac{1}{16} + \frac{1}{4}$, the LCD is _____.<br>b. $\frac{4}{7} - \frac{1}{49}$, the LCD is _____. |
| a. 16<br>b. 49 | 40. After the LCD has been determined, change all fractions to equivalent fractions of the same denominator; then add or subtract. Example: $\frac{2}{7} + \frac{1}{42}$, the LCD is 42. To change $\frac{2}{7}$ to LCD 42: Divide 7 into 42; the quotient is 6. Multiply 6 by the numerator 2 and place the product (12) over the LCD. $\frac{2}{7} = \frac{12}{42}$. Now we can add. $\frac{12}{42} + \frac{1}{42} = \frac{13}{42}$ reduced is $\frac{13}{42}$ .<br>Change the fractions below so they have the same LCD.<br>a. $\frac{1}{3} + \frac{5}{6} + \frac{1}{12} =$ _____ + _____ + _____<br>b. $\frac{4}{5} - \frac{1}{3} =$ _____ - _____ |

Continue to page 19

18A

You have the correct fraction but made a mistake in the addition of whole numbers. Now return to page 22B and work the problem again. Do not just pick the other answer without first re-working the problem to find your error.

18B

Incorrect. You've made a mistake someplace in changing fractions to equivalent fractions of the same denominator. Return to page 17, Frame 40, re-read the rule, then go back to page 14B and choose the other answer.

18C

$\frac{1}{4}$ is wrong. You did not obtain the reciprocal of the divisor.

$\frac{2}{3}$ inverted is $\frac{3}{2}$ and the reciprocal of $\frac{2}{3}$ is also $\frac{3}{2}$.

Go back to page 2C, rework the problem, and select the correct answer.

| | |
|---|---|
| a. $\frac{4}{12} + \frac{10}{12} + \frac{1}{12}$<br>b. $\frac{12}{15} - \frac{5}{15}$ | 41. Find the LCD and change the fractions below to equivalent fractions.<br>a. $\frac{1}{9} + \frac{1}{81} + \frac{2}{3} =$ _____ + _____ + _____<br>b. $\frac{4}{5} - \frac{5}{8} =$ _____ - _____ |
| a. $\frac{9}{81} + \frac{1}{81} + \frac{54}{81}$<br>b. $\frac{32}{40} - \frac{25}{40}$ | 42. The rule again for adding and subtracting fractions. (1) Change fractions to common denominators. (2) Add or subtract numerators. (3) Keep common denominator. (4) Reduce answers to lowest terms. At your left and below are the LCD problems from the last frame. Complete the problems.<br>a. $\frac{9}{81} + \frac{1}{81} + \frac{54}{81} =$ _____ reduced _____<br>b. $\frac{32}{40} - \frac{25}{40} =$ _____ reduced _____ |
| $\frac{64}{81}$ reduced is $\frac{64}{81}$<br>$\frac{7}{40}$ reduced is $\frac{7}{40}$ | 43. Does it all come back to you now? Solve this problem and reduce answer to lowest terms.<br>$\frac{1}{28} + \frac{6}{7} + \frac{5}{14} =$ _____<br>If your answer is: — Go to page:<br>$1\frac{1}{4}$ — 14B<br>$1\frac{7}{28}$ — 16B<br>$\frac{12}{28}$ — 12C<br>$\frac{3}{7}$ — 10C |
| You came from page 24A.<br>a. $1\frac{2}{7}$<br>b. 1 [illegible]/8<br>c. $13\frac{9}{16}$<br>d. $1\frac{2}{4}$ | 44. When multiplying two or more fractions, multiply numerators of the fractions to obtain numerator of the product. To obtain the numerator of the product in the problem $\frac{2}{3} \times \frac{2}{3}$, multiply _____ (number) times _____ (number). |

Continue to page 21

20A

Very good. Work the following problem by subtracting mixed numbers. Reduce answer to lowest term. $16\frac{8}{15} - 15\frac{3}{5} =$ ______

| If your answer is: | Go to page: |
|---|---|
| $1\frac{14}{15}$ | 22A |
| $\frac{14}{15}$ | 24A |
| $\frac{6}{15}$ | 16C |
| can't be solved | 26C |

---

20B

Good. $1\frac{19}{20}$ is correct. Now try one on subtraction and reduce answer to lowest terms. $\frac{4}{13} - \frac{3}{39} =$ ______.

| If your answer is: | Go to page: |
|---|---|
| $\frac{3}{13}$ | 22B |
| $\frac{3}{39}$ | 31A |

---

20C

No. $6\frac{29}{36}$ is incorrect. Again you forgot to invert the divisor. The divisor $1\frac{1}{6}$ is changed to $\frac{7}{6}$ and inverted is $\frac{6}{7}$. Now go back to page 28B and select another answer.

| | |
|---|---|
| 2<br>2 | 45. Like the numerator, the denominator of the product is obtained by multiplying the denominators of the fractions. In the problem $\frac{2}{3} \times \frac{4}{5}$, the numerator of the product is obtained by multiplying ____________ times ____________ and the denominator is obtained by multiplying ____________ times ____________. |
| 2 x 4<br>3 x 5 | 46. The rule, then, for multiplying fractions is: "Multiply numerators of the fractions to obtain the ____________ of the product and multiply the denominators to obtain the ____________ of the product." Solve this problem: $\frac{2}{3} \times \frac{2}{5} =$ ____________. |
| numerator<br>denominator<br>$\frac{4}{15}$ | 47. The word "of" is sometimes used in place of the multiplication sign "x". $\frac{2}{3}$ of $15 = 10$ can be written as $\frac{2}{3} \times \frac{15}{1} = \frac{30}{3} = 10$. Solve this problem and reduce: $\frac{5}{8}$ of $40 =$ _____ reduced _____. |
| $\frac{200}{8}$<br>reduced = 25 | 48. If the problem contains more than two fractions, multiply all the numerators and multiply all the denominators. Example:<br>$\frac{2}{5} \times \frac{1}{3} \times \frac{2}{3} \times \frac{1}{4} = \frac{4}{180}$ reduced $\frac{1}{45}$<br>Solve this problem:<br>$\frac{3}{5} \times \frac{4}{7} \times \frac{1}{2} =$ ____________ reduced = ____________ |

Continue to page 23

22A

You've forgotten the rule on borrowing.

$$\begin{array}{rcccl} 16\frac{8}{15} & = & 16\frac{8}{15} & = & 15\frac{23}{15} \\ -\,15\frac{3}{5} & = & 15\frac{9}{15} & = & 15\frac{9}{15} \\ \hline \end{array}$$

You cannot subtract $\frac{9}{15}$ from $\frac{8}{15}$, so you have to borrow a whole number (1). $1 = \frac{15}{15}$, which you now add to the $\frac{8}{15}$. Don't forget now that you borrowed a whole number from 16. Go back to page 20A. Re-work the problem and select the correct answer.

22B

Good. Now for the rule for adding and subtracting mixed numbers:

1. Change fractions to like fractions (LCD). 2. Add/subtract the fractions. 3. Add/subtract the whole numbers. 4. Reduce answers to lowest terms. Example: $1\frac{1}{3} + 3\frac{11}{12}$ and $7\frac{1}{2} - 4\frac{1}{5}$.

$$\begin{array}{rcl} 1\frac{1}{3} & = & 1\frac{4}{12} \\ +\,3\frac{11}{12} & = & 3\frac{11}{12} \\ \hline & & 4\frac{15}{12} = 4 + 1\frac{3}{12} = 5\frac{1}{4} \end{array} \qquad \begin{array}{rcl} 7\frac{1}{2} & = & 7\frac{5}{10} \\ -\,4\frac{1}{5} & = & 4\frac{2}{10} \\ \hline & & 3\frac{3}{10} \end{array}$$

Now add these fractions: $7\frac{1}{9} + 6\frac{5}{18} + \frac{1}{6} =$ _____.

| If your answer is: | Go to page: |
|---|---|
| $14\frac{5}{9}$ | 18A |
| $13\frac{5}{9}$ | 20A |

| | |
|---|---|
| $\frac{12}{70}$<br>reduced = $\frac{6}{35}$ | 49. "Cancellation" is a "short cut" used in multiplying fractions. The short cut in multiplying fractions is called ____________. |
| cancellation | 50. Cancellation is much the same as reducing. The first step is to select a numerator and denominator that can be divided evenly by the same number. The problem $\frac{5}{10} \times \frac{2}{5} \times \frac{4}{10}$ can be reduced to: $\frac{\overset{1}{\cancel{5}}}{\underset{5}{\cancel{10}}} \times \frac{\overset{1}{\cancel{2}}}{\underset{1}{\cancel{5}}} \times \frac{\overset{2}{\cancel{4}}}{\underset{5}{\cancel{10}}}$. The next step is to multiply the numerators and the denominators $\frac{1}{5} \times \frac{1}{1} \times \frac{2}{5} = \frac{2}{25}$ reduced is $\frac{2}{25}$. Solve the problem below by cancellation. Show work.<br>$\frac{5}{8} \times \frac{4}{7} \times \frac{1}{5} =$ _____. |
| $\frac{\overset{1}{\cancel{5}}}{\underset{2}{\cancel{8}}} \times \frac{\overset{1}{\cancel{4}}}{7} \times \frac{1}{\underset{1}{\cancel{5}}} = \frac{1}{14}$ | 51. When you use the cancellation method, the basic principle is: Dividing both the numerator and the denominator by the same number does not change the value of a fraction. The value of a fraction is not changed when the ____________ and the ____________ are ____________ by the same number. |
| numerator<br>denominator (either order)<br>divided | 52. In the problem $\frac{2}{15} \times \frac{3}{8}$, the 2 and 8 can be cancelled by dividing each by ____________ and the 3 and 15 cancelled by dividing each by ____________. The answer to the problem, then, is ____________. |

Continue to page 25

24A

Very good. The idea here was to see if you remember how to borrow. Solve the addition and subtraction problems below. Answers must be in lowest terms.

a. $\frac{1}{21} + \frac{4}{7} + \frac{2}{3} =$
b. $3\,\frac{3}{8} - 2\,\frac{1}{4} =$
c. $11\,\frac{1}{8} + 1\,\frac{3}{16} + \frac{1}{2} + \frac{3}{4} =$
d. $14\,\frac{1}{6} - 12\,\frac{5}{12} =$

Go to page 19, Frame 44, to check answers and continue from there.

---

24B

5 is the correct answer. Try one more.

$$5\,\frac{4}{7} \div 3 =$$

| If your answer is: | Go to page: |
|---|---|
| $1\,\frac{6}{7}$ | 29B |
| $16\,\frac{5}{7}$ | 30A |
| $\frac{13}{7}$ | 28A |

| | |
|---|---|
| 2<br>3<br>$\frac{1}{20}$ | 53. In the problem $\frac{10}{13} \times \frac{26}{50} \times \frac{7}{21}$, the 10 and 50 are cancelled by dividing each by ______________; the 13 and 26 are cancelled by dividing each by ______________; and $\frac{7}{21}$ can be reduced to __________.<br>Now solve the problem, showing your cancellation.<br>$\frac{10}{13} \times \frac{26}{50} \times \frac{7}{21} =$ ______________. |
| 10; 13; $\frac{1}{3}$<br>$\frac{\overset{1}{\cancel{10}}}{\underset{1}{\cancel{13}}} \times \frac{\overset{2}{\cancel{26}}}{\underset{5}{\cancel{50}}} \times \frac{\overset{1}{\cancel{7}}}{\underset{3}{\cancel{21}}} =$<br>ans. $\frac{2}{15}$ | 54. Solve the following problems, using cancellation where applicable. Reduce answers to lowest terms.<br>a. $\frac{2}{5} \times \frac{3}{10} \times \frac{7}{9} =$<br>b. $\frac{12}{16} \times \frac{8}{24} \times \frac{8}{10} =$ |
| a. $\frac{7}{75}$<br>b. $\frac{1}{5}$ | 55. In order to multiply fractions and mixed numbers, the mixed numbers must be changed to improper fractions.<br>Example: $2\frac{1}{2} \times \frac{3}{8} \times 1\frac{1}{3}$ will be changed to<br>$\frac{5}{2} \times \frac{\overset{1}{\cancel{3}}}{\underset{2}{\cancel{8}}} \times \frac{\overset{1}{\cancel{4}}}{\underset{1}{\cancel{3}}} = \frac{5}{4}$ reduced is $1\frac{1}{4}$<br>Solve the following problems, using cancellation where applicable, and reduce answers to lowest terms;<br>a. $3\frac{1}{3} \times 5\frac{1}{2} \times \frac{9}{10} =$<br>b. $4\frac{1}{2} \times 3\frac{1}{3} \times 2\frac{2}{8} =$<br>c. $\frac{3}{4}$ of 80 = |

Continue to page 27

26A

Not quite. $\frac{35}{7}$ is an improper fraction and for the answer to be completely correct (lowest terms), you must now change your answer to a mixed number. Return to page 28B, recheck your work, and reduce answer to lowest terms.

26B

4 or $\frac{4}{1}$ is incorrect. You obtained the reciprocal of the dividend. You're to obtain the reciprocal of the divisor and then proceed as in multiplication. Now go to page 2C, rework the problem, and select the correct answer.

26C

You've forgotten the rule on borrowing. True, you can't subtract $15\frac{9}{15}$ from $16\frac{8}{15}$ unless you borrow. Why not take one (1) from 16 and add the fraction $\frac{15}{15}$ to $\frac{8}{15}$? Now you can subtract, but don't forget the one (1) you borrowed. Go back to page 20A, rework the problem, and select another answer.

| | |
|---|---|
| a. $16\frac{1}{2}$<br>b. $33\frac{3}{4}$<br>c. 60 | 56. Solve the problems below, cancelling where applicable, and reduce answers to lowest terms.<br>a. $\frac{3}{5}$ of $2\frac{5}{8} =$<br>b. $3\frac{1}{2} \times 2\frac{1}{4} \times \frac{2}{3} =$<br>c. $\frac{1}{6}$ of $24 =$<br>d. $2\frac{1}{8} \times 3\frac{3}{4} \times 1\frac{1}{3} =$ |
| a. $1\frac{23}{40}$<br>b. $5\frac{1}{4}$<br>c. 4<br>d. $10\frac{5}{8}$ | 57. Dividing common fractions requires two steps:<br>Example: $\frac{2}{7} \div \frac{1}{3} =$<br>Dividend Divisor<br>(1) Obtain reciprocal of divisor (invert divisor) — — $\frac{3}{1}$.<br>(2) Multiply the dividend by the reciprocal of the divisor — — $\frac{2}{7} \times \frac{3}{1} = \frac{6}{7}$.<br>Then $\frac{2}{7} \div \frac{1}{3} =$ ____. |
| $\frac{6}{7}$ | 58. Fill in the steps to find $\frac{5}{9} \div \frac{3}{4}$.<br>(1) Obtain reciprocal of divisor (invert the divisor). ____<br>(2) Multiply the dividend by the reciprocal of the divisor. ____<br>Then $\frac{5}{9} \div \frac{3}{4} =$ ____. |
| $\frac{4}{3}$<br>$\frac{5}{9} \times \frac{4}{3}$<br>$\frac{20}{27}$ | 59. Solve this problem: $\frac{3}{10} \div \frac{3}{4}$<br>If your answer is: Go to page:<br>$\frac{2}{5}$ 2C<br>$\frac{9}{40}$ 4C.<br>$\frac{12}{30}$ 29A |

28A

$\frac{13}{7}$ is unacceptable, because answers will always be reduced to their lowest terms. Return to page 24B and select the correct answer that is in its lowest terms.

28B

$\frac{9}{16}$ is correct.

Dividing with mixed numbers requires three steps: (1) Change the mixed number or mixed numbers to improper fractions. (2) Obtain the reciprocal of the divisor (invert divisor). (3) Multiply the dividend by the reciprocal of the divisor.

Try this problem: $5\frac{5}{6} \div 1\frac{1}{6} =$

| If your answer is: | Go to page: |
|---|---|
| 5 | 24B |
| $6\frac{29}{36}$ | 20C |
| $\frac{35}{7}$ | 26A |

29A

Not quite right. You must not have cancelled the 3's after obtaining the reciprocal of the divisor and you haven't reduced to the lowest terms. Go back to page 27, frame 59, and correct your mistake. Then select the correct answer.

29B

$1\frac{6}{7}$ is correct. Divide the following fractions and reduce answers to lowest terms:

a. $\frac{5}{8} \div \frac{3}{4} =$

b. $22 \div 6\frac{7}{8} =$

c. $2\frac{1}{6} \div 4\frac{1}{2} =$

d. $\frac{8}{21} \div 3\frac{3}{7} =$

GO TO PAGE 30B TO CHECK YOUR ANSWERS.

30A

No! Does it sound reasonable that 3 is contained in $5\frac{4}{7}$ - - - 16 and $\frac{5}{7}$ times ? You forgot to obtain the reciprocal of the divisor before you multiplied. Go back to page 24B, invert the divisor, multiply, and then select the correct answer.

---

30B

Answers from page 29B: a. $\frac{5}{6}$ b. $3\frac{1}{5}$ c. $\frac{13}{27}$ d. $\frac{1}{9}$

If you had any answers other than those above, you must rework the problem(s on page 29B. When you've gotten all correct, solve these problems:

a. $5\frac{2}{3} \div 9\frac{5}{9} =$

b. $5\frac{2}{5} \times 2\frac{1}{4} \times 4\frac{2}{3} =$

c. $21\frac{1}{16} + 9\frac{3}{8} + 8\frac{1}{2} + \frac{3}{4} =$

d. $3\frac{3}{16} - 1\frac{3}{4} =$

GO TO PAGE 32A TO CHECK YOUR ANSWERS.

31A

Never! The only way you could have arrived at this answer was to have reduced the numerator and not the denominator. Return to page 20B, work the problem again, and select the correct answer.

32A

Answers from page 30B:

a. $\frac{51}{86}$ b. $56\frac{7}{10}$ c. $39\frac{11}{16}$ d. $1\frac{7}{16}$

If you missed any problem, you must rework and recheck. After all problems are correct, read the rules again that are on the pages listed below and then go to page 32B.

| Problem: | Go to page: |
|---|---|
| a. (division) | 28B |
| b. (multiplication) | 25, Frame 55 |
| c. (addition) | 22B |
| d. (subtraction and borrowing) | 22A |

After you've read the rules again, go to page 32B.

32B

You have completed the Programmed Lesson on fractions. For some, the program was just a review; for others, it has been a process of learning.

A SELF-TEST ON FRACTIONS COMMENCES ON PAGE 33.

322

## SELF-TEST ON FRACTIONS

1. Write the definition of a fraction.

______________________________________________

2. Identify the two parts of the fraction $\frac{7}{8}$ and explain what each part shows.

7-- ____________________________________________

______________________________________________

8-- ____________________________________________

______________________________________________

3. Identify the proper fractions, the improper fractions, and the mixed numbers in the following list by placing a "P" by the proper fractions, an "I" by the improper fractions, and a "M" by the mixed number.

a. $\frac{15}{16}$

b. $\frac{19}{17}$

c. $2\frac{4}{5}$

d. $\frac{9}{7}$

e. $77\frac{2}{3}$

f. $\frac{300}{299}$

g. $\frac{10}{11}$

h. $\frac{7}{12}$

i. $6\frac{3}{7}$

j. $\frac{5}{6}$

4. Change the mixed numbers to improper fractions and the improper fractions to mixed numbers.

a. $3\frac{2}{3}$

b. $\frac{11}{10}$

c. $12\frac{4}{5}$

d. $\frac{19}{15}$

e. $7\frac{7}{8}$

Continue to page 34

5. Reduce the following fractions to their lowest terms:

a. $\frac{18}{81}$

b. $\frac{9}{12}$

c. $\frac{21}{63}$

d. $\frac{3}{7}$

e. $\frac{14}{21}$

f. $\frac{16}{64}$

6. Solve the following ADDITION and SUBTRACTION problems. Reduce answers to lowest terms.

a. $\frac{1}{2} + \frac{1}{2} =$

b. $\frac{5}{7} - \frac{2}{3} =$

c. $\frac{3}{8} + \frac{3}{4} =$

d. $2\frac{3}{8} - 1\frac{5}{8} =$

e. $6\frac{7}{10} - 4\frac{4}{5} =$

f. $11\frac{3}{4} + 19\frac{5}{8} + 9\frac{1}{2} + \frac{3}{16} =$

7. Multiply the following fractions, cancelling where applicable. Reduce answers to lowest terms.

a. $\frac{1}{2} \times \frac{3}{4} \times \frac{2}{3} =$

b. $4\frac{2}{3} \times 5\frac{1}{4} \times 2\frac{2}{3} =$

c. $\frac{3}{4} \times 5\frac{1}{2} =$

d. $\frac{1}{8}$ of $16 =$

8. Divide the following fractions, cancelling where applicable. Reduce answers to lowest terms.

a. $\frac{7}{8} \div \frac{7}{16} =$

b. $15 \div 4\frac{1}{5} =$

c. $4\frac{2}{3} \div 12\frac{4}{9} =$

d. $\frac{4}{5} \div 2\frac{7}{15} =$

Answers to Self-Test on
page i in front of text

2TPT-5111-02

Technical Training

# Basic Mathematics - Decimals

17-4

April 1967

SHEPPARD AIR FORCE BASE

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by
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Designed For ATC Course Use

## ANSWERS TO SELF-TEST

## DECIMALS

1. A decimal is a number that represents a fraction with a denominator that is a power of ten.

2. a. (30.04 thirty and four hundredths)

   b. (.379 three hundred seventy-nine thousandths)

   c. (1.46 one and forty-six hundredths)

   d. (90.001 ninety and one thousandths)

3. a. 9.75 b. 12.3 c. 7.123 d. .0073

4. a. .3 b. .8 c. .75 d. 2.5

5. a. $\frac{1}{4}$ b. $\frac{9}{10}$ c. $\frac{21}{200}$ d. $\frac{7}{20}$

6. a. .6 b. 13.85 c. .057 d. 1.6001

7. a. 25.886 b. 180.553 c. 19.3925

8. a. 10.18 b. .6298 c. 446.37

9. a. .3093 b. .00284 c. .32012

10. a. 20 b. .001 c. .5

## INSTRUCTIONS

## DECIMALS

This is a programmed lesson on DECIMALS. It is not a test as one might think, but an easy way to learn at your own rate of speed.

The two types of programming used in this lesson are:

a. Linear-- Information, in small amounts, will be presented in sequence. You will advance from frame to frame, using a provided cardboard to cover upcoming frames. Do not look ahead at answers. IF YOU MAKE AN ERROR, strike out the incorrect answer and correct it.

b. Branching-- The information given in these frames will be greater and you will be given a list of possible answers. Directions to turn to a page for each answer will be found next to the answers. FOLLOW THESE DIRECTIONS. Circle the answer you think is correct. If you have selected an incorrect answer, put an X through the incorrect response and circle another answer.

READ ALL INFORMATION CAREFULLY. Be sure you understand what is said before you attempt an answer.

If you wish, you may turn back to any part of the program to clarify some vague point.

While working problems in the program, if you are instructed to SHOW ALL WORK, you must work in the program. Otherwise, you may do the work EITHER on scratch paper or in the program.

Continue to page iii

# DECIMALS

OBJECTIVES:

1. Write, in his own words, the definition of a decimal.
2. Demonstrate ability to read decimals by matching numerical decimals with the appropriate word decimals.
3. Write the numerical form of given word decimals.
4. Change given fractions to decimals.
5. Change given decimals to fractions. Reduce the fractions to lowest terms.
6. Round off given decimals.
7. Add given decimals.
8. Subtract given decimals.
9. Multiply given decimals.
10. Divide given decimals.

SUGGESTED READING TIME— 62 MINUTES

NAME ____________________

CLASS ____________

Continue to page 1.

| | |
|---|---|
| | 1. The definition of a decimal is: A number that represents a fraction with a denominator that is a power of ten. The definition of a decimal is:<br>______________________________________________<br>______________________________________________. |
| a number that represents a fraction with a denominator that is a power of ten | 2. Being a power of ten simply means that you can divide ten into the number evenly. The fraction $\frac{47}{100}$ has a denominator of one hundred and, of course, ten will divide evenly into it. We know that 100 is a power of ____________. |
| 10 or ten | 3. All decimals represent fractions and in every case the denominator is a power of ten. The decimal, .1, represents the fraction $\frac{1}{10}$ . The denominator is a __________ of ____________. |
| power<br>ten | 4. The definition of a decimal is: A number that represents a fraction with a ____________ that is a ____________ of ____________. |
| denominator<br>power<br>ten | 4A. Key words often help you remember hard to learn definitions. In the definition of DECIMAL, the words to remember as keys are: FRACTION, DENOMINATOR, and POWER OF TEN.<br>Write the key words that will help you remember the definition of decimal.<br>____________, ____________, and ____________. |

Continue to page 2.

| | |
|---|---|
| fraction<br>denominator<br>power of ten | 5. A decimal is a number that represents a ____________ with a ____________ that is ________________________________________. |
| fraction<br>denominator<br>a power of ten | 6. Write, in your own words, the definition of a decimal<br>________________________________________<br>________________________________________. |
| a number that represents a fraction with a denominator that is a power of ten (or a reasonable facsimile). | 7. Each digit in a decimal has a place value and is read in a certain way. The places are as follows:<br>.12345<br>1 Tenths<br>2 Hundredths<br>3 Thousandths<br>4 Ten Thousandths<br>5 Hundred Thousandths<br>The 3 is in the thousandths place, the 5 is in the hundred thousandths place,and the 1 is in the ____________ place. |
| tenths | 8. As you probably have noticed, the places to the right of the decimal point all end in "ths." In the decimal 2.46, the 6 is in the ____________ place. |
| hundredths | 9. A decimal is read like this: (Example)<br>35.362-- "Thirty-five AND three hundred sixty-two thousandTHS".<br>The 2 in this decimal is in the ____________ place. |

Continue to page 3.

| | |
|---|---|
| thousandths | 10. When there is a whole number and a decimal, the decimal point is read "AND". For example: 6.02 is read "six AND two hundredths".<br>When there is only a decimal (no whole number), it is read without using the word, "and". For example: .06 is read "six hundreths".<br>How would "thirty-three THOUSANDTHS" be written as a decimal? ______________. |
| .033 | 11. REMEMBER-- When you are reading decimals, the decimal point is read "and" except when there is NO whole number. For example: .5 is read "five tenths". 3.22 is read "three AND twenty-two hundredths".<br>Match the decimal in column A with the correct word decimal in column B, placing the correct letter by the word decimal.<br>A<br>a. 4.3<br>b. .006<br>c. 25.01<br>________Six hundreds<br>________Twenty-five and one hundredth<br>________Six hundredths<br>________Four and three tenths<br>________Twenty-five and one tenth<br>________Six thousandths |

Continue to page 5.

4A

Very good! You should be ready for a more difficult problem, so let's do this one:

Change $\frac{12}{23}$ to a decimal.

| If your answer is: | Go to page: |
|---|---|
| .0052 | 6A |
| .52 | 8B |

---

4B

Wrong!! You add only the number of zeros that there are digits in the decimal. There is only one digit in the decimal .7, so there will be only one zero in the fraction. The decimal .679 has three digits, so the denominator will have three zeros and look like:

| If your answer is: | Go to page: |
|---|---|
| 679/1000 | 16A |
| 679/000 | 8C |

a. 4.3 (four and three tenths)

b. .006 (six thousandths)

c. 25.01 (twenty-five and one hundredth)

12. Now, match column A with column B in the same manner.

| A | B |
|---|---|
| a. .25 | ______ Two hundredths |
| b. .002 | ______ One and two hundred twenty-two thousandths |
| c. 20.05 | ______ Twenty-five hundredths |
| d. 1.222 | ______ Two thousandths |
| | ______ Twenty and five hundredths |
| | ______ Twenty-five hundred |
| | ______ One and two hundred twenty-two thousands |

a. .25 (twenty-five hundredths)

b. .002 (two thousandths)

c. 20.05 (twenty and five hundredths)

d. 1.222 (one and two hundred twenty two thousandths)

NOTE: Be certain the word decimal ends with "ths."

13. When writing a decimal, FIRST and MOST IMPORTANT, determine the "place" value (thousandths, tenths etc.). This will give you the number of digits you need to the right of the decimal point. For example: twenty-two thousandths will require three digits because it is to the thousandths place. It would be written: .022

Five and five tenths would be written: 5.5

(Remember, with a whole number, the decimal point is read AND.)

How would twenty-five and four thousandths be written? ____________

Continue to page 7.

6A

Wrong. You set your division up incorrectly. The problem should have been set up like this: $23\overline{)12.000}$

Return to page 4A and do the division again and place the decimal point in the right position; then select the right answer and go to the page indicated.

6B

3/4 is not correct; .75=3/4. Return to page 10 and work the problem again. Then select the correct answer and continue with the program.

6C

You have misplaced the decimal point. The decimal point ALWAYS goes to the extreme right of the dividend. EXAMPLE: $\overline{)12.}$ not $\overline{)1.2}$, from $\frac{12}{7}$. Return to page 8B; rework the problem and continue with the program.

6D

Your division is right, but it is unnecessary to put the 0 at the end of the decimal. Turn to page 4A and continue the program.

| | |
|---|---|
| 25.004 | 14. Thirteen and four tenths would appear as 13.4<br>Nine and forty-four hundredths appear as:<br>______________ |
| 9.44 | 15. Four ten thousandths looks like ______________. |
| .0004 | 16. Write the numerical form of twenty-nine thousandths.<br>______________ |
| .029 | 17. Write the numerical form of each of the following word decimals.<br>a. Sixty-five hundredths<br>______________<br>b. Sixty and ninety-seven thousandths<br>______________<br>c. Three hundred and four tenths<br>______________<br>d. Seventy-five ten thousandths<br>______________<br>e. Fifty-eight and sixty-six hundredths<br>______________<br>f. Forty-nine thousandths<br>______________ |

Continue to page 9.

**8A**

$\frac{45}{1000}$ is correct for the first step, but each fraction must be in its lowest terms. 5 divides into 45 and 1000— thus it can be reduced. Go back to page 16A and reduce the fraction, choose the correct answer, and go to the page indicated.

**8B**

.52 is correct. You have been changing proper fractions to decimals, so now let's change an IMPROPER FRACTION to a decimal. It is done in the same manner, but NOW the answer will include a whole number. For example: $\frac{3}{2}$ changed to a decimal is

$$\begin{array}{r} 1.5\phantom{.} \\ 2\overline{)3.0.} \\ \underline{2\phantom{.0.}} \\ 1\ 0\phantom{.} \\ \underline{1\ 0\phantom{.}} \end{array}$$

. As you can see, an improper fraction will become a whole number and a decimal (1.5). Change $\frac{12}{7}$ to a decimal.

| If your answer is: | Go to page: |
|---|---|
| .17 | 6C |
| 1.7 | 18A |

**8C**

You have the 3 zeros but what happened to the 1? The decimal .679 is read "six hundred seventy-nine thousandths", so the denominator becomes 1000. Return to page 4B and select the correct answer.

a. .65
b. 60.097
c. 300.4
d. .0075
e. 58.66
f. .049

18. All fractions can be changed to a decimal by dividing the numerator by the denominator. The decimal may be carried out as many places as the problem indicates. Example: $\frac{7}{8}$ to a decimal is

$\begin{array}{r} .875 \\ 8\overline{)7.000} \end{array}$ BROKEN INTO STEPS:

a. Divide the numerator (7) by the denominator (8).

b. Place the decimal point to the right of the numerator.

c. Add zeros to the right of the decimal point as needed.

d. Place a decimal point in the quotient DIRECTLY over the decimal point in the division bracket.

e. Carry the quotient out as far as necessary.

Change $\frac{1}{2}$ to a decimal.

| If your answer is: | Go to page: |
|---|---|
| 2.0 | 16B |
| .5 | 4A |
| 5.0 | 18C |

---

If you are reading this paragraph, then you are not following directions. From here on, you must follow the directions given in each frame VERY CAREFULLY. Return to the frame above and follow the directions given there.

ANSWERS TO PAGE 18A: a. .8 b. 5.2 c. .8 d. 1.3

You have learned how to change a fraction to a decimal, so let's change a decimal into a fraction. The FIRST thing to do is to make the digits of the decimal the NUMERATOR OF THE FRACTION. The denominator of the fraction will have a one (1) followed by the same number of zeros as there are digits in the decimal. For example, the decimal .27 becomes the fraction $\frac{27}{100}$. Notice how the digits 27 become the numerator and the denominator begins with a 1 and two zeros follow. There were two digits in the decimal, thus there are two zeros in the denominator.

Change .7 to a fraction.

| If your answer is: | Go to page: |
|---|---|
| $\frac{7}{100}$ | 4B |
| $\frac{7}{10}$ | 16A |
| $\frac{3}{4}$ | 6B |

11A

Fine. As you have done on this problem, make sure that any fraction you are working with is in its lowest terms. Change the following decimals to fractions. Remember, REDUCE each to its lowest terms. If you still are not certain of just how to change decimals to fractions, go back to page 10 and rapidly review.

Change these to fractions:

a. .7000--

b. .009--

c. .75--

d. .2--

Turn to page 12 for answers.

---

11B

You neglected the decimal point. You must place decimal points DIRECTLY UNDER EACH OTHER. The sum will have the decimal point carried right down into it from the column being added. Return to page 17A and do the problem again. Remember to put the decimal points under each other. EXAMPLE:

```
   18.6
     .015
 2056.11
+   1.1
 2075.825
```

ANSWERS TO PAGE 11A: a. $\frac{7}{10}$ b. $\frac{9}{1000}$ c. $\frac{3}{4}$ d. $\frac{1}{5}$

Continue your lesson in frame 19 below.

19. In many cases, a large cumbersome decimal is not necessary. In those cases where a smaller decimal will do, you may ROUND OFF the decimal. To make a large decimal smaller and easier to use without losing a great deal of accuracy, you will ____________ ____________ the large decimal.

round off

20. Rounding off involves THREE steps. The FIRST TWO are:

a. Determine the PLACE you want to round off to. (Tenths, hundredths, etc.)

b. Look FIRST at the number (digit) DIRECTLY to the right of that place.

Example: .176

To round to hundredths: First look at the number to the right of the hundredths place. In this case, it is a 6.

The FIRST number that you will look at when rounding .265 to TENTHS is ______ (number).

Continue to page 13.

| | |
|---|---|
| 6 | 21. You have the decimal .27364, and you want to round it off to tenths. What number would you look at first? (Circle your choice.)<br>a. 2<br>b. 7<br>c. 3<br>d. 6<br>e. 4 |
| 7 | 22. The THIRD STEP is:<br>If the number to the right of the place you are rounding off is 5 OR MORE, you ADD (+1) one to the place and drop the remainder of numbers.<br>For example: .176<br>This decimal rounded to tenths becomes .2 because the number to the right of the tenths place (7) is 5 or greater. Also note that the 7 and 6 were dropped.<br>Round .0074 to the nearest HUNDREDTH. (Circle your answer.)<br>a. .01<br>b. .007<br>c. .1<br>d. .08 |
| .01 | 23. When the number to the right is LESS THEN 5, leave the place value as is and DROP THE REMAINDER OF THE NUMBERS.<br>Round the decimal .7848 to hundredths. (Circle your answer.)<br>a. .78 b. .79 c. .785 d. .7800 |

Continue to page 14.

| | |
|---|---|
| .78 | 24. REMEMBER:<br>a. FIRST, look at the number to the right of the place you are rounding off.<br>b. If the number is 5 or more, add 1 to the place.<br>c. If less then 5, do not add anything.<br>d. Always drop the remainder of digits to the right of the rounded off place.<br>Round these decimals to the indicated places:<br>Tenths: .408062 ________<br>Hundredths: .408062 ________<br>Thousandths: .408062 ________<br>Ten Thousandths: .408062 ________<br>Hundred Thousandths: 408062 ________ |
| .4<br>.41<br>.408<br>.4081<br>.40806 | 25. Round off the following decimals:<br>To Hundredths:<br>41.1145-- ________<br>.98509-- ________<br>To Tenths:<br>.6419-- ________<br>To Ten Thousandths:<br>.29826-- ________<br>1.11181-- ________ |

Continue to page 15.

| | |
|---|---|
| Hundredths<br>41.11<br>.99<br><br>Tenths.<br>.6<br><br>Ten Thousandths<br>.2983<br>1.1118 | 26. If you are NOT having trouble with rounding off, proceed to frame 27. If you are and your trouble is mainly knowing the "places", turn to page 2, frame 7, and review. If you do not understand how to round off, review or raise your hand for assistance.<br>When you have corrected your trouble, continue to frame 27.<br>* NO RESPONSE REQUIRED. * |
| | 27. Round off each of the following decimals to the indicated place.<br>To the nearest tenth: To the nearest hundredth:<br>a. .329-- __________ c. .10909-- __________<br>b. .05-- __________ d. 8.3434-- __________<br>To the nearest thousandth:<br>e. .2551-- __________<br>f. 5.9738-- __________<br>To the nearest ten thousandth:<br>g. 7.777774-- __________<br>h. .000891-- __________<br>To the nearest hundred thousandth:<br>i. .0980653-- __________<br>j. 3.000051-- __________<br><br>Turn to page 17A for answers. |

16A

Very good. The next thing to remember is: Make sure the fraction is in its lowest terms. For example, changing the decimal .5 to a fraction, it first becomes $\frac{5}{10}$. Is this in the lowest terms possible? Of course, the answer is no. In its lowest terms, it would be $\frac{1}{2}$. Always check the fraction and be sure it is in its lowest terms. Try this one now. Change .045 to a fraction.

| If your answer is: | Go to page: |
|---|---|
| $\frac{9}{200}$ | 11A |
| $\frac{45}{1000}$ | 8A |
| $\frac{45}{100}$ | 21B |

16B

In order to change a fraction to a decimal, you divide the numerator by the denominator. You did not do this. In the case of $\frac{1}{2}$, the denominator (2) is divided into the numerator (1) like this:

$$\begin{array}{r} .5 \\ 2\overline{)1.0} \\ 1\ 0 \end{array}$$

$\frac{1}{2}$ changed to a decimal is therefore .5 . ALL fractions are changed to decimals in the same manner.

Change $\frac{3}{4}$ to a decimal.

| If your answer is: | Go to page: |
|---|---|
| .750 | 6D |
| .75 | 4A |

17A ANSWERS TO PAGE 15 FRAME 27:

a. .3 b. .1 c. .11 d. 8.34 e. .255 f. 5.974

g. 7.7778 h. .0009 i. .09807 j. 3.00005

You will now learn the last four objectives-- How to ADD, SUBTRACT, MULTIPLY, AND DIVIDE decimals. Continue below.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Adding decimals is much the same as simple whole number addition. The difference is that there is a decimal point to keep in mind. The decimals are put in a column and decimal points are under decimal points (see example). The decimal point is brought down to the sum and the addition is carried on just as it is in whole number addition.

EXAMPLE:

$$\begin{array}{r} 6.3 \\ .01 \\ \underline{22.22} \\ 28.53 \end{array}$$

Add these decimals. 33.79 + .97 + 2.2 =

| If your answer is: | Go to page: |
|---|---|
| 36.96 | 19A |
| 3498 | 11B |

---

17B

Wrong. The number to the right of the division sign is always the divisor.

.064 ÷ 3.2 (3.2 is the divisor, not .064.)

Return to page 26 and select the correct answer.

18A

Right. If you want to review before you do the problems below, return to page 9, frame 18, read the rules, and then come back and solve the problems. If you think you are ready now, then change each of the fractions below to decimals.

a. $\frac{4}{5}$

b. $\frac{52}{10}$

c. $\frac{9}{11}$

d. $\frac{13}{10}$

Turn to page 10 to check answers and continue from there.

---

18B

No. Move the decimal point in the dividend the same number of places as you did in the divisor. Example: $3.2\overline{).064}$ because $3\underset{\curvearrowright}{2}.\overline{)\underset{\curvearrowright}{0}.64}$. Return to page 26 and select the correct answer.

---

18C

You set up your problem incorrectly and had the decimal in the wrong place. This is what you should have set up for your division: $2\overline{)1.00}$ . Return to page 9, frame 18, and determine the correct answer. Then turn to the correct answer page.

19A

Right. The main thing to remember is to keep the decimal points lined up under each other. Now let's subtract decimals. The rules are the same as they are in the subtraction of whole numbers. Just as in the addition of decimals, the decimal points must be lined up under each other. You must also remember that the smaller of the numbers must go under the larger.

Solve this problem: 729.75308 - .0077=

| If your answer is: | Go to page: |
|---|---|
| 729.75231 | 20B |
| 729.74538 | 22 |

---

19B

ANSWERS TO PAGE 24A: a. 66.42 b. .825 If your answers are not correct, make the corrections and continue below.

Now let's divide decimals. The most important factor is that the divisor must be "made" a whole number before division is started. This is done by moving the decimal in the divisor all the way to the right.

Ex: $.25\overline{)\quad\quad}$ becomes $\underset{\curvearrowright}{25}.\overline{)\quad\quad}$. Then move the decimal in the dividend the same number of places to the right. Ex: $.25\overline{)1.25}$ becomes $\underset{\curvearrowright}{25}.\overline{)\underset{\curvearrowright}{125}.}$ Move the decimal point in the following division problem and solve.

$$3.3\overline{).66\quad}$$

Turn to page 24B.

20A

Right. **REMEMBER:** The divisor is to the right of the division sign.

Solve these problems and show your work.

a. 4.9 ÷ .007= b. 1179 ÷ 13.1= c. .02925 ÷ 2.25=

WORK HERE - -

a. b. c.

Go to page 23B for answers.

20B

Remember when you were told that decimal points must go under decimal points? Well, the error you made was because of the decimal placement. A good way to remember the decimal points is put them on the paper first (in a column) and then put the numbers down. Also remember to put the decimal in the answer DIRECTLY under those in the column. Go back to page 19A and do the problem again.

20C

No. DO NOT ADD an extra zero on the right of any answer. If you need zeros to make your digit count correct, they must go to the left of the answers. For example: .2 x .002 will equal .0004, not .4000.

Return to page 23A and select the correct answer.

21A

Your decimal point should have been placed like this:

```
    3.217
  x  .471
     3217
    22519
   12868
 1.515207
```

If you had it any place else, return to page 22 and read the rules again.

If you did it correctly, do the following problems by placing the decimal points correctly in the product.

```
a.     .0035          b.   22.222
     x  3.28             x    .11
         280               22222
          70              22222
        105               244442
       11480
```

Turn to page 23A.

---

21B

There are more than two digits in the decimal .045. Zero IS a digit. That makes three digits in this decimal. You should use the same number of zeros as there are digits and make the denominator 1000. Return to page 16A and select the correct answer.

Right. You are now ready for multiplication. Decimals are multiplied just as whole numbers are, except you have a decimal point to put in the final answer (product). DISREGARD the decimal point in the first two steps. A sample problem is broken into steps to clarify the process.

PROBLEM: .15 x 1.10 =

a. Place the larger number OVER the smaller. Ex.

$$\begin{array}{r} 1.10 \\ \underline{\times\ .15} \end{array}$$

b. Multiply just as you do in whole numbers. Ex.

$$\begin{array}{r} 1.10 \\ \underline{\times\ .15} \\ 550 \\ \underline{110\phantom{0}} \\ 1650 \end{array}$$

c. Count the number of digits to the right of the decimal points in the factors of the problem. Ex. 1.10 and .15 = 4 digits to the right in this case,

d. Count off 4 places FROM THE RIGHT in the PRODUCT, and place a decimal point. Ex. .1650 (product of this problem)

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Another example: 3.1 x 10.21 (would be set up and solved like this):

$$\begin{array}{rl} 10.21 & \\ \underline{\times\ \ 3.1} & \\ 1021 & \\ \underline{3063\phantom{0}} & \\ 31.651 & \text{product} \end{array}$$

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Place the DECIMAL POINT in the product of this problem:

$$\begin{array}{r} 3.217 \\ \underline{\times\ \ .471} \\ 3217 \\ 22519\phantom{0} \\ \underline{12868\phantom{00}} \\ 1515207 \end{array}$$

Turn to page 21A.

23A

ANSWERS TO PAGE 21A: a. .011480 or .01148 b. 2.44442

Let's try another to make sure that you have the decimal point placement down pat. Solve this one: .55 x .003 =

| If your answer is: | Go to page: |
|---|---|
| .01650 | 20C |
| .00165 | 24A |

23B

ANSWERS TO PAGE 20A: a. 700 b. 90 c. .013

Solve these problems: (SHOW ANSWERS.)

a. 289.0038 + .992763 =
b. .3928 - .02867 =
c. .42 x 3.7 =
d. 4.32 ÷ .0036 =

WORK ON SCRATCH PAPER.

Turn to page 25.

24A

Very good. Care must be taken with your arithmetic. It is always a good idea to CHECK your multiplication and addition. This is where most of the errors are made, with a few being made on the placement of the decimal point.

Let's try two more. After completing them, check your arithmetic and decimal placement.

a. $332.1 \times .2 =$ b. $.55 \times 1.5 =$

TURN TO PAGE 19B.

---

24B

$3.3\overline{).66}$ becomes $\begin{array}{r} .2 \\ 33_{\wedge}.\overline{)6_{\wedge}.6} \end{array}$ by moving the decimal point one place.

When the divisor IS a whole number and the dividend is a decimal, such as $33\overline{)6.4}$, you do not move the decimal point. Simply place the decimal point up in the quotient directly over the decimal point in the dividend; then divide. For example: $\begin{array}{r} . \\ 275\overline{)3.44} \end{array}$

Solve this: $26\overline{)7.8}$

The answer to the problem above is: (Circle your answer.)

a. 3

b. .3

c. .03

Turn to page 26.

ANSWERS TO PAGE 23B

a.
$$\begin{array}{r} 289.003800 \\ +\ \underline{\phantom{289}.992763} \\ 289.996563 \end{array}$$

b.
$$\begin{array}{r} .39280 \\ -\ \underline{.02867} \\ .36413 \end{array}$$

c.
$$\begin{array}{r} .42 \\ \underline{\times\ 3.7} \\ 294 \\ \underline{126\phantom{0}} \\ 1.554 \end{array}$$

d.
$$\begin{array}{r} 1200\phantom{.} \\ 36\overline{)43200.} \\ \underline{36}\phantom{000.} \\ 72\phantom{00.} \\ \underline{72}\phantom{00.} \end{array}$$

If you missed any of these problems, go to the part of the program that teaches that type of problem and read the rules again. THEN correct your error. The pages that teach each function are listed below.

ADDITION (Page 17A)

SUBTRACTION (Page 19A)

MULTIPLICATION (Page 22)

DIVISION (Pages 19B & 26)

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

This completes your lesson in decimals. Working partial numbers is easier when you use decimals rather than fractions, so this lesson is very important.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

A Self-Test begins on page 27.

$26\overline{)7.8}$ solved is: $\begin{array}{r} .3 \\ 26\overline{)7.8} \end{array}$

If the dividend IS a whole number, Ex: $1.32\overline{)25.}$, add zeros and move the decimal point. Ex: $1.\underset{\curvearrowright}{32}\overline{)\underset{\curvearrowright}{25.00}}$. When the decimal has been moved as appropriate, then place a decimal point in the quotient directly over the point in the dividend, Ex: $2.\underset{\curvearrowright}{5}\overline{)\underset{\curvearrowright}{.1}\uparrow 00}$ and solve.

Example: $\begin{array}{r} .04 \\ 2.\underset{\curvearrowright}{5}\overline{)\underset{\curvearrowright}{.1}\uparrow 00} \end{array}$

NOTICE HOW THE QUOTIENT IS .04 AND NOT .4. THIS IS BECAUSE 25 GOES INTO 10 ZERO TIMES, AND INTO 100 FOUR TIMES.

Solve the problem below:

$.064 \div 3.2 =$

Note: ÷ is the sign for division and the number on the right is always the divisor.

| If your answer is: | Go to page: |
|---|---|
| $\begin{array}{r} 50. \\ \underset{\curvearrowright}{.064}\overline{)\underset{\curvearrowright}{3.200.}} \end{array}$ | 17B |
| $\begin{array}{r} .2 \\ \underset{\curvearrowright}{3.2}\overline{)\underset{\curvearrowright}{.064}} \end{array}$ | 18B |
| $\begin{array}{r} .02 \\ 3.\underset{\curvearrowright}{2}\overline{)\underset{\curvearrowright}{.06}4} \end{array}$ | 20A |

## SELF-TEST

## DECIMALS

1. Write, in your own words, the definition of a decimal.

______________________________________________

______________________________________________

2. Match the numerical decimals in Column A with the appropriate word decimals in Column B. Place the letter from Column A in the blank next to the correct word decimal in Column B.

| A | B |
|---|---|
| a. 30.04 | _____ One hundred forty-six |
| b. .379 | _____ Three hundred seventy-nine thousandths |
| c. 1.46 | _____ Thirty and four hundredths |
| d. 90.001 | _____ Ninety-one thousands |
| | _____ Three hundred seventy-nine thousand |
| | _____ One and forty-six hundredths |
| | _____ Thirty-four hundredths |
| | _____ Ninety and one thousandths |

3. Write the numerical form of the following word decimals:

   a. Nine and seventy-five hundredths __________

   b. Twelve and three tenths __________

   c. Seven and one hundred twenty-three thousandths __________

   d. Seventy-three ten thousandths __________

4. Change the fractions below to decimals.

a. $\frac{3}{10}$ =     c. $\frac{3}{4}$ =

b. $\frac{4}{5}$ =     d. $\frac{5}{2}$ =

5. Change the decimals below to fractions. REDUCE TO LOWEST TERMS.

a. .25 =     c. .105 =

b. .9 =     d. .35 =

6. Round off the following decimals as directed.

NEAREST TENTH:

a. .6354 -

NEAREST THOUSANDTH:

c. .05671 -

NEAREST HUNDREDTH:

b. 13.8467 -

NEAREST TEN THOUSANDTH:

d. 1.60006 -

7. Add the following decimals:

a. 9.37 + 15.756 + .76 =

b. 69.333 + .12 + 111.1 =

c. .0055 + 7.02 + 12.367 =

8. Subtract the following decimals:

a. 13.14 - 2.96 =

b. .7068 - .077 =

c. 447.3 - .93 =

9. Multiply the following decimals:

a. .03 x 10.31 =

b. .71 x .004 =

c. 1.51 x .212 =

10. Divide the following decimals:

a. .08 ÷ .004 =

b. .00344 ÷ 3.44 =

c. .04 ÷ .08 =

END

**Answers to the Self-Test are found on page i in the front of the text.**

ATC-SHEPPARD AFB TEX. 78-1173

357

TECHNICAL TRAINING

17-4

# BASIC PHYSICS - MATTER

April 1967

SHEPPARD AIR FORCE BASE

Original Material Prepared
by
Naval Air Technical Training Command

Designed For ATC Course Use

358

## ASSIGNMENT SHEET

This assignment sheet should be used when:

- You are to complete only a part of this text.
- Your assignment within this text is divided into two or more reading periods.

Your instructor will make assignments by identifying specific objectives, text material, and review questions.

ASSIGNMENTS

| OBJECTIVES (by No) | TEXT MATERIAL (by Page) | REVIEW QUESTIONS (by No) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

# MATTER

## OBJECTIVES

1. Write the definition of matter.
2. List the three states of matter.
3. Identify the states of matter from a given list of diagrams which show the transfer of each state of matter from one container to another.
4. Match the terms volume, mass, universal attraction, weight, density, inertia, porosity, impenetrability with a list of statements describing these terms.
5. Draw the "Magic Circle" for weight, volume, and density; and write the formula for finding:
   a. weight
   b. volume
   c. density
6. Match the terms element, compound, molecule, and atom with a list of statements describing these terms.

SUGGESTED READING TIME 57 MINUTES

| | |
|---|---|
| | 1. The earth and the planets, or anything that can be found on or in them, take up space and have weight (a vacuum does not have weight).<br>These things are called matter.<br>Matter is anything that has weight and occupies ____________________. |
| SPACE | 2. The pencil you are writing with has weight and occupies space. The pencil, therefore, is considered ________________. |
| MATTER | 3. You are surrounded by matter. The air you breathe, the food you eat, your own body are all matter. These things and anything that has weight and occupies space are called __________________. |
| MATTER | 4. The definition of matter is anything that ________ ____________ and ____________ ____________. |
| HAS WEIGHT<br>OCCUPIES SPACE | 5. What is the definition of matter?<br>______________________________________<br>______________________________________ |

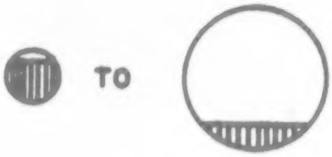
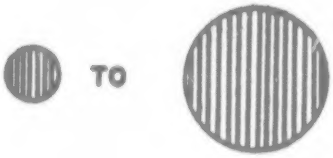
CONTINUE ON PAGE 3

(From page 6A)
2A

You will be embarrassed when you return to page 6A and look at the diagram you said represents a solid. Go back now and think about your choice. You will find that it does not have the properties of a solid. Choose the correct one and continue the program.

(From pages 4A or 6B)
2B

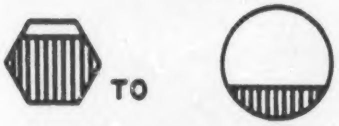
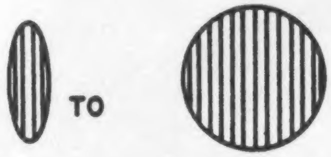
Good. You know how liquids react and look when transferred from one container to another. Gases will react in a certain way, too. They will assume the shape and the volume of a new container, as shown by helium being blown into a balloon. A set of diagrams showing the transfer of gas from one container to another would look like:

| If your answer is: | Turn to page: |
|---|---|
| <br>TO | 4B |
| <br>TO | 6A |

| | |
|---|---|
| ANYTHING THAT HAS WEIGHT AND OCCUPIES SPACE. | 6. Matter exists as a solid. It also exists as a gas and a liquid.<br>The three states in which matter exists are ____________, ________________, and ____________. |
| SOLID<br>LIQUID<br>GAS | 7. Water, blood, and gasoline are liquids. Steel, wood, and ice are solids. Oxygen, $CO_2$, and water vapor are gases. Gases, solids, and liquids are the three ____________ of ______________. |
| STATES<br>MATTER | 8. What are the three states of matter?<br>1. ____________________<br>2. ____________________<br>3. ____________________ |
| SOLID<br>LIQUID<br>GAS | 9. Each state of matter behaves differently when moved from one container to another. When the gas from a can of "Spare Tire" is released into a tire, it occupies the volume and assumes the shape of the tire. If milk is poured from a pint bottle into a quart pan, will the liquid assume the shape and the volume of the pan?<br>If your answer is: Turn to page:<br>Yes 4A<br>No 6B |

(From page 3, frame 9)
4A

Incorrect. It does not assume the volume of the pan. If you pour the milk (1 pint) into the pan (1 quart), will it fill the pan? Of course not, but it will assume the shape. This is the way liquids react in the transfer process. They assume the shape but NOT the VOLUME. The transfer of liquid shown as a diagram would look like:

| If your answer is: | Turn to page: |
|---|---|
|  | 2B |
|  | 8A |

(From page 2B)
4B

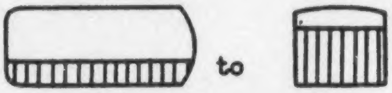
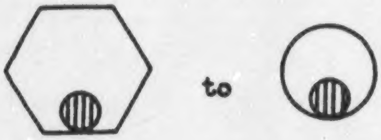
Gas will take up the entire space and assume the shape of the new container when transferred. Return to page 2B and look at the diagrams; see which set of diagrams represents a gas and then turn to the correct answer page.

| | |
|---|---|
| | 10. You are not reading what you should be! If you had followed instructions, you wouldn't be reading this frame. Return to frame 9 and continue the program. |
| ANSWER TO 20A<br>$W = DV$<br>$D = \frac{W}{V}$<br>$V = \frac{W}{D}$ | (From page 20A)<br>11. An ELEMENT is a substance that cannot be reduced to simpler substances by chemical means. Gold, oxygen, and platinum cannot be reduced to simpler substances by ____________________ means because they are ____________________. |
| CHEMICAL<br>ELEMENTS | 12. A substance that cannot be broken down into a simpler substance by chemical means is called a/an ____________________. |
| ELEMENT | 13. Elements are the basic substances that are combined to form the many things that we know as compounds. Water and sugar are examples of compounds because they are a combination of two or more elements. An element cannot be reduced to a ________________ ____________________ by chemical means, and a/an ____________________ is made up of two or more elements. |

CONTINUE ON PAGE 7

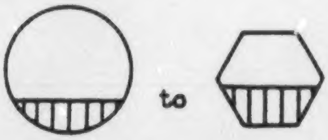
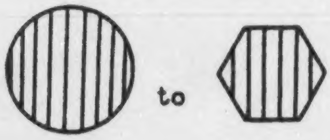
(From page 2B)
6A

Right. You have shown that you know a gas will take the size and shape of a new container if transferred. So far, you know what liquids and gases do when they are transferred from one container to another. Solids react entirely differently. They assume NEITHER the shape nor the volume of the new container. Move a block of wood from a small box to the back of a truck. It does not change in shape or volume. Shown as a diagram, transfer of solids would look like:

| If your answer is: | Turn to page: |
|---|---|
|  | 2A |
|  | 10B |

(From page 3, frame 9)
6B

Very good. As you have shown, liquids assume the shape of a new container but not the volume (unless the two volumes are the same). This can be shown in a diagram, which might look like:

| If your answer is: | Turn to page: |
|---|---|
|  | 2B |
|  | 13B |

| | |
|---|---|
| SIMPLER SUBSTANCE<br>COMPOUND | 14. There are many common things that are elements or compounds. Hydrogen, iron, aluminum, carbon, and tin are all examples of ________________ because it has been found that they cannot be broken down or changed into something simpler (by chemical means). |
| ELEMENTS | 15. Some common examples of compounds are earth, wood, paper, salt, and air. In order to be classed as a compound, the substance must have at least ______________ elements. |
| TWO (2) | 16. Plastic, cotton, and air can all be reduced to a material or substance that is simpler or different, since they are made up of several different elements. They are known as ____________________. |
| COMPOUNDS | 17. Matter is made up of very small particles called atoms and molecules. These two small particles are different, since it takes 2 or more atoms to make a molecule. Another way to say it is-- an atom combined with another atom or atoms makes a/an __________________. |

CONTINUE ON PAGE 9

(From page 4A)
8A

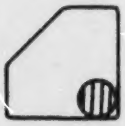
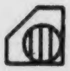
Wrong. The diagram shows that the liquid is assuming the shape and the volume. Liquids will assume the shape and the volume ONLY when the two containers have the same volume . This, of course, is not characteristic of liquids. Go to page 4A and choose the diagrams showing the transfer of liquid from one container to another.

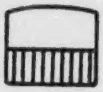
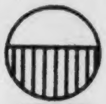
---

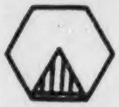
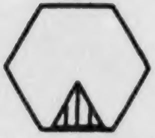
(From page 10B)
8B

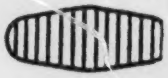
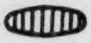
ANSWERS TO PAGE 10B - - a. L, b. S, c. G

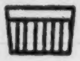
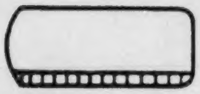
Identify the state of matter in the diagrams below that show the transfer of matter from one container to another. The shaded area represents matter. Fill in the blank between each set of diagrams, using a G for gas, L for liquid, and S for solid.

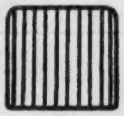
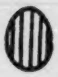
a.  ____ 

b.  ____ 

c.  ____ 

d.  ____ 

e.  ____ 

f.  ____ 

Turn to page 10A

| | |
|---|---|
| | (From frame 17, page 7) |
| MOLECULE | 18. An atom is the smallest particle of an element that can combine with other atoms to form molecules. A molecule is the smallest part of a substance that will have all the characteristics of that substance. The smallest part of water that still has all the properties of water is a/an ______________________. |
| MOLECULE | 19. A molecule will have all the properties of a substance. The particles that make up the molecules and do not necessarily have any of the properties of the substance are called ____________________. |
| ATOMS | 20. Remember that a/an ____________ does not have to have any of the properties of the substance of which it is a part. The smallest particle of a substance that does have all the properties of it is a/an ______________________. |

CONTINUE ON PAGE 11A

(From page 8B)
10A

ANSWERS TO PAGE 8B - - a. S, b. L, c. S, d. G, e. L, f. G.

There are several general properties which all matter has in common. These are: volume, mass, universal attraction, weight, density, inertia, porosity, and impenetrability. Would steel have the same general properties as wood?

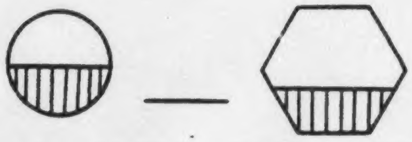
| If your answer is: | Turn to page: |
|---|---|
| Yes | 14B |
| No | 12A |

(From page 6A)
10B

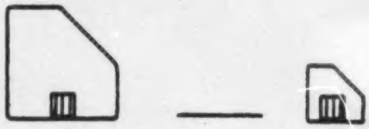
RIGHT. As a quick review-- liquids assume the shape but not the volume; gas will take both the new shape and volume; a solid will not change either its shape or its volume. All these transfers from container to container can be shown by diagrams.

Identify the states of matter in the diagrams below. Use G for gas, L for liquid, and S for solid.

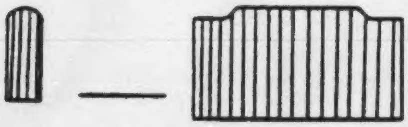
a.



b.



c.



Turn to page 8B

(From page 9, frame 20)
11A

ANSWERS TO FRAME 20 - - atom, molecule

Identify each statement below as a description of either an element, compound, molecule, or atom. Write the name in the provided blank.

a. Something that is made up of several different elements.

_____________________

b. A small particle that when combined with other particles of similar size makes a molecule. _____________________

c. This cannot be reduced to a simpler substance by chemical means. _____________________

d. The smallest part of a substance that retains all the properties of that substance. _____________________

TURN TO PAGE 14C

---

(From page 15A)
11B

Very good. Apparently you know how to use the magic circle. Any one of the three properties is just as easy to find. Turn to page 17A to check your understanding of the magic circle.

---

(From page 13A)
11C

Your answer, water, is incorrect. Remember that density is the weight per unit volume of matter. The density of mercury is 850 pounds per cubic foot, whereas fresh water has a density of 62.5 pounds per cubic foot. In other words, a unit volume of mercury (in this case, a cubic foot) weighs more than a unit volume of water; consequently, mercury is denser than water. Now return to page 13A and select the correct answer.

371

(From page 10A)
12A

Your answer, no, is incorrect. We said that there were several general properties which all matter has in common. Even though steel and water are different states of matter, they are still matter; and, therefore, have the same general properties. Return to page 10A and select the correct answer.

(From page 14B)
12B

You're right, very good. All matter occupies space; therefore, it has volume. The next general property we will cover is mass. The measure of the quantity of matter in a body is called its mass. The mass of a given body is constant-- it does not vary. As an example of mass, consider a sponge. It contains a definite measurable amount of mass. Whether we squeeze, stretch, or soak the sponge in water, the mass will not change, even though the size and shape may be altered. The amount of sponge will remain unchanged. In other words, the mass of the sponge will remain constant.

If you squeeze a rubber ball, you are also decreasing its mass.

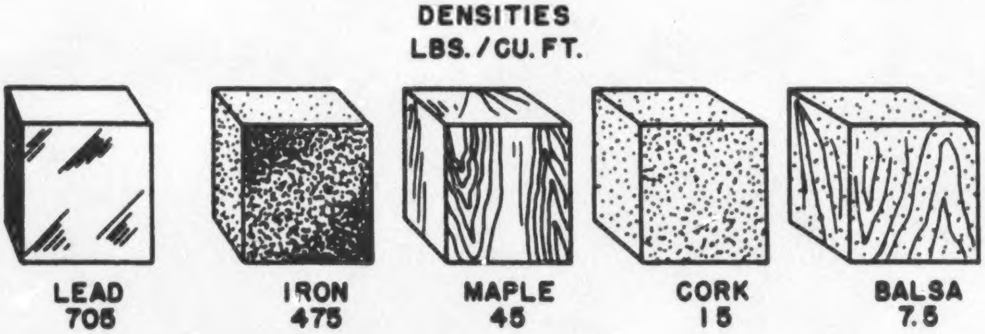
| If your answer is: | Turn to page: |
|---|---|
| True | 18D |
| False | 14A |

393

(From page 16A)
13A

Weight is the attractive force of the earth for a body.

The next general property of matter we will cover is density. Density is the weight of a unit volume of matter. Iron is denser than wood. This means that one cubic foot of iron weighs more than one cubic foot of wood. The more matter (mass) there is in a given volume of a substance, the denser that material is. Shown below are some examples of densities.



Which would be denser, water or mercury?

| If your answer is: | Turn to page: |
|---|---|
| water | 11C |
| mercury | 20B |

(From page 6B)
13B

Wrong. The diagram shows that the liquid is assuming the shape and the volume. Liquids will assume the shape and the volume ONLY when the two containers have the same volume. This, of course, is not characteristic of liquids. Go back to page 6B and choose the correct answer.

(From page 12B)
14A

You selected false, and you're right. Always remember that the mass of a given body is constant. The next general property of matter we will cover is universal attraction. All matter attracts all other matter. This fact was first stated by Sir Isaac Newton, and it is known as Newton's law of universal gravitation. As an example, the earth is bound to the sun by the mutual attraction of the matter contained in the sun and the earth. Would universal attraction have anything to do with why we are bound to the earth?

| If your answer is: | Turn to page: |
|---|---|
| Yes | 16A |
| No | 19B |

(From page 10A)
14B

You are absolutely right. We said that the general properties of matter were common to all matter.

Let's now discuss each one of the general properties of matter, starting with volume.

If matter occupies space, as we found it does, it must have length, width, and height. In other words, volume is the measure of the amount of space which matter occupies.

Does gas have volume?

| If your answer is: | Turn to page: |
|---|---|
| Yes | 12B |
| No | 15B |

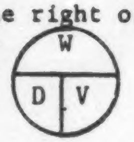
(From page 11A)
14C

ANSWERS TO PAGE 11A: a. Compound b. Atom c. Element d. Molecule

This completes the program on matter. Review the objectives before taking the self-test.

(From page 16B)
15A

No. You can only put the other two values to the right of the = sign. Thus W=VD. The formula was derived like this---



W = DV

As you notice in the circle, the V and the D are side by side. They are also side by side when they are substituted in the formula. If you want to find the volume or the density, then your formula will change. What is the formula for finding volume?

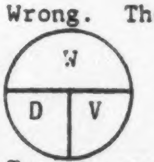
| If your answer is: | Turn to page: |
|---|---|
| $W = DV$ | 17B |
| $V = WD$ | 19A |
| $V = \frac{W}{D}$ | 11B |

(From page 14B)
15B

Wrong, think again. Doesn't the air, which is a gas, occupy a certain amount of space in a balloon? The $CO_2$ in a life raft occupies a certain amount of space, doesn't it? The volume of gas is determined by the size of the container in which it is contained and this quantity of volume is measured in cubic units, such as cubic inches, cubic feet, etc. Now return to page 14B and select the correct answer.

(From page 18A or 18C)
15C

Wrong. The formula for finding volume is not V = WD. The magic circle



has the W OVER the D. It would become $V = \frac{W}{D}$.

Turn to page 17A and continue the program.

(From page 14A)
16A

You're right. We are attracted to the earth, as is the earth attracted to us, by universal attraction (gravitation). Of course, the farther away from the earth's surface a body is, the less gravitational attraction there will be on that body.
Now, let's move on to the next general property of matter --- weight. The attraction of the earth for a body acts as a pull on that body. We may say that the earth exerts an attractive force on the body. The measure of the attractive force of the earth for a body is called the weight of the body. As an example, if you weigh 145 pounds, the mass of your body and the mass of the earth mutually attract each other with a force of 145 pounds. Therefore, weight is the ______________________

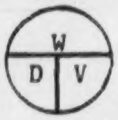
______________________________________________________.

Turn to page 13A

(From page 19C)
16B

Answers from page 19C. -- 1 - G, 2 - E, 3 - F, 4 - A. 5 - B, 6 - C, 7 - D, 8 - H.

Now let me introduce you to the "Magic Circle."



W= Weight
V= Volume
D= Density

There is nothing magic about it, but it does make memory work a little easier. With it, we can find any ONE of three characteristics of matter (volume, density, or weight). You must know two in order to find the third. To do this, take the one you wish to find from the circle and place the letter to the left of the = sign. Then place the other two, just as they appear in the circle, to the right of the = sign. For instance, if you wish to find the weight of an object, take the W out of the circle, put an = sign after it, and place the remaining two known values after the = sign like this:

| If your answer is: | Turn to page: |
|---|---|
| $W = \frac{W}{VD}$ | 15A |
| $W = DV$ | 13A |
| $W = \frac{V}{D}$ | 18C |

(From page 11B, 15C, 18A, 18C, or 19A)

17A

Right! You should be ready for a test in writing formulas and the magic circle. If you don't feel you can derive a formula from the magic circle, return to page 16C and go through the frames on the magic circle again; otherwise, draw the magic circle and write the formula for finding density.

**Magic Circle** **Formula**

Turn to page 18B for answer

(From page 15A)

17B

$W = \rho V$ is the formula for finding weight, not volume. The unknown must go to the left of the = sign; so, for finding volume, the V goes to the left (V=). Return to page 15A and select the correct formula as you get it from the magic circle.

(From page 22A)

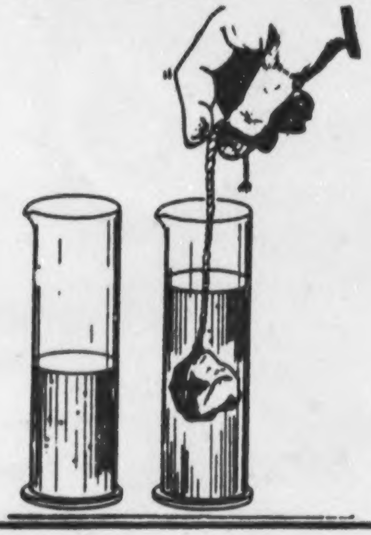
17C

Yes, water will seep through a cement block foundation unless the blocks are waterproofed because of the porous nature of cement.

The last general property of matter we will cover is impenetrability. No two objects can occupy the same space at the same time because all matter is impenetrable. A nail driven into a board does not penetrate the wood, but pushes the fibers aside. The drawing shown below illustrates the impenetrability of matter. Explain why. ____________________

__________________________________________________________

__________________________________________________________



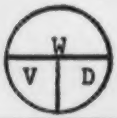
CONTINUE ON PAGE 22B

(From page 16B)
18A

Very good. As you have indicated by your formula, the W is taken from the magic circle and placed to the left of the = sign. The V and the D are side by side. This, of course, means volume times density = weight. If you were going to find the volume of an object, the formula would be:

| If your answer is: | Turn to page: |
|---|---|
| $V = WD$ | 15C |
| $V = \frac{W}{D}$ | 17A |

(From page 17A)
18B

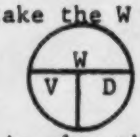
ANSWERS TO PAGE 17A: 

and $D = \frac{W}{V}$

Turn to page 20A

(From page 16B)
18C

No. $W = \frac{V}{D}$ is not correct. If you take the W from the magic circle, to find weight you will have this ---



The V and the D are side by side. It is also that way in the formula. $W = DV$ means weight equals volume times density.

If you want to find the volume of an object, you substitute from the magic circle and have this formula:

| If your answer is: | Turn to page: |
|---|---|
| $V = WD$ | 15C |
| $V = \frac{W}{D}$ | 17A |

(From page 12B)
18D

Wrong. Remember, we said that the mass of a given body is constant; it does not vary. By squeezing the rubber ball, all we have done is change its volume. Now return to page 12B and select the correct answer.

(From page 15A)
19A

Draw a magic circle ... Now look at the W and the D. Are they side by side as you indicated in your formula? As you have noticed by now, the W is OVER the D with a line between them. The problem asked for the formula for finding volume. As you take the letters from the magic circle, they will fall right into their proper places and look like this:

$$V= \frac{W}{D}$$

Turn to page 17A and continue the program.

(From page 14A)
19B

Your answer, no, is incorrect. Remember, universal attraction means that all matter attracts all other matter. Therefore, we are bound to the earth's surface by a certain force because of the attraction between our bodies and the earth's surface.
Now return to page 14A and select the correct answer.

(From page 22B)
19C

Match the terms with the statements.

1. Weight________
2. Volume________
3. Mass ________
4. Universal attraction ______
5. Density________
6. Inertia________
7. Porosity_______
8. Impenetrability____

A. All matter attracts all other matter
B. The weight of a unit volume of matter
C. Matter lacks the ability to either start or stop itself.
D. All matter is granular (space between particles).
E. The measure of the amount of space which matter occupies
F. The measure of the quantity of matter in a body. It is constant.
G. The measure of the attractive force of the earth for a body
H. No two objects can occupy the same place at the same time.

CONTINUE ON PAGE 16B

(From page 18B)

20A

Draw the magic circle for weight, density, and volume, and write the formulas for finding weight, density, and volume.

Magic Circle here: Formulas here:

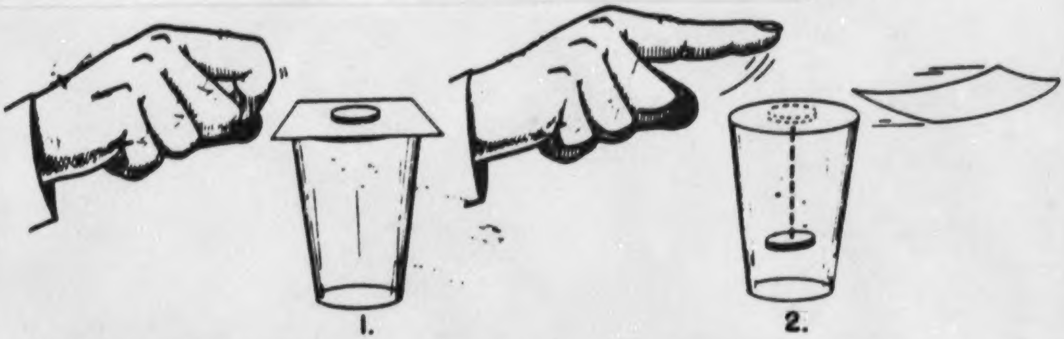
Turn to page 5, frame 11

(From page 13A)

20B

Very good. Mercury is denser than water. Remember, we said that density is the weight of a unit volume of matter. The density of water (fresh) is 62.5 pounds per cubic foot, whereas the density of mercury is approximately 850 pounds per cubic foot.

The next general property of matter we will cover is inertia. According to Newton's law of inertia, a body continues in its state of rest, or uniform motion, unless an unbalanced force acts on it. In other words, matter lacks the ability to either start or stop itself. Some examples of inertia are-- the inability to stop a speeding car when the brakes fail and the inability of an aircraft to make a carrier landing without arresting gear. In the sketch shown below, the inertia of the coin (inability to start itself) allows us to flick the card from under it, and the coin drops directly into the glass.



Would inertia ever be a factor on your body if you were a passenger riding in an automobile? Yes/No __________

Give an example. ______________________________

______________________________

______________________________

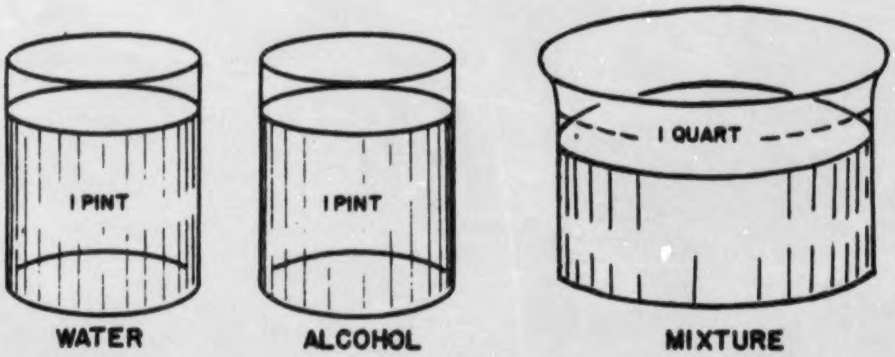
______________________________

Turn to page 21A

(From page 20B)
21A

Yes, it would. An example might be as follows: if you were a passenger riding in a car traveling at 60 miles per hour and the car stopped suddenly, what would be the action of your body if you were not wearing seat belts? According to the law of inertia, a body in motion continues in motion unless acted upon by an outside force. Therefore, your body would be thrown forward and through the windshield. If the car accelerated suddenly, the action of your body would be being thrown against the back of the seat. These are both examples of inertia.

Porosity is the next general property of matter we will cover. All matter is granular, that is, it has space or pores between the particles. The amount of space between the particles depends upon the structure of the material. In the sketch shown below, notice that when a pint of water and a pint of alcohol are mixed, they do not equal a quart of the mixture.

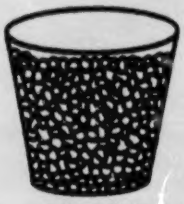


This would suggest that the alcohol partially fills the spaces between the particles of water.

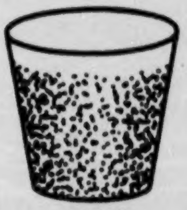
CONTINUE ON PAGE 22A

(From page 21A)
22A

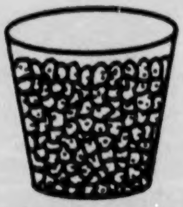
To illustrate the point more clearly, look at the illustration below.



**COARSE GRAVEL**



**SAND**



**COARSE GRAVEL AND SAND**

If we had two similar containers, one filled with gravel and one filled with sand, and if both of these containers were emptied into a larger one, the container with the sand and gravel mixture would not be completely full, because the sand would fill the spaces between the gravel. Could water seep through the cement foundation of a house? Yes/No

Why? ____________________

____________________

____________________

____________________

Continue on page 17C

(From page 17C)
22B

Impenetrability of matter is shown in the illustration because the water level rises. The object being lowered into the water takes some of the water's space, which indicates that no two objects can occupy the same place at the same time.

Continue on page 19C

## SELF-TEST

## MATTER

1. Write the definition of matter.

____________________________________________

____________________________________________

2. List the three states of matter.

1. ____________________

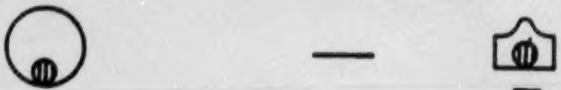
2. ____________________

3. ____________________

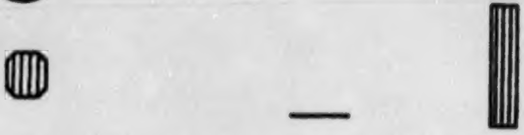
3. Identify the state of matter by writing a G for gas, S for solid, and L for liquid in the spaces provided between each set of diagrams, showing the transfer of states of matter from container number 1 to container number 2. The lined area represents the space occupied by matter.

**CONTAINER NO. 1** **CONTAINER NO. 2**

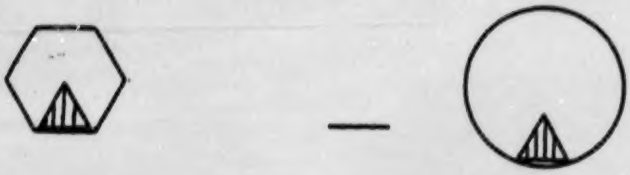
a. ____



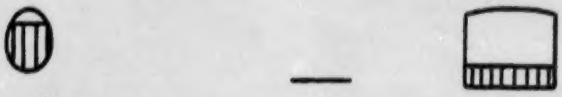
b. ____



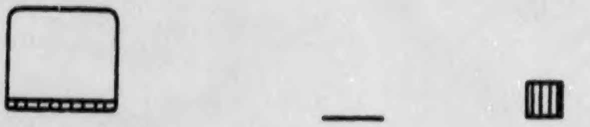
c. ____



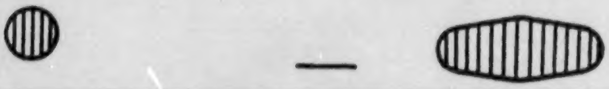
d. ____



e. ____



f. ____



4. Match the terms volume, mass, universal attraction, weight, density, inertia, porosity, and impenetrability with the list of statements describing these terms.

1. Weight _____
2. Volume _____
3. Mass _____
4. Universal attraction _____
5. Density _____
6. Inertia _____
7. Porosity _____
8. Impenetrability _____

A. All matter attracts all other matter.
B. The weight of a unit volume of matter.
C. Matter lacks the ability to either start or stop itself.
D. All matter is granular (space between particles).
E. The measure of the amount of space which matter occupies.
F. The measure of the quantity of matter in a body. It is constant.
G. The measure of the attractive force of the earth for a body.
H. No two objects can occupy the same place at the same time.

5. Draw the "Magic Circle" for weight, volume, and density, and write the correct formula for finding each of them.

Weight ----

Volume ----

Density ---

Draw the magic circle here

6. Identify each of the following phrases or statements as an element, compound, molecule, or atom. Place the correct name in the space provided below **the statement.**

a. Matter that contains several different elements.

______________________________

b. The smallest particle of an element that can combine with other particles to form molecules.

______________________________

c. Water, trees, dirt, and snow are all examples of

______________________________.

d. Gold, hydrogen, and mercury cannot be reduced to a simpler substance by chemical means. They are known as

_____________________________.

e. A substance that is broken down to the smallest particle possible and still retains all the properties of that substance is a/an

_____________________________.

f. Each particle that combines with other particles to form a molecule is called a/an

_____________________________.

g. Matter that cannot be reduced to a simpler substance by chemical means is known as a/an

_____________________________.